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(54) Interactive copying system.

(57) A system for generating new documents (20) from originals (4) containing text and/or images (22,28) employing e.g. a camera-projector system (6,8) focussed on a work surface (2), in conjunction with a copier or printer. In use, the camera 6 captures various manual operations carried out by the user, e.g. by pointing with fingers and tapping on the surface on the text or images (22,28) in an original paper document (4) on the surface (2) and representing manipulations of the text or images (22,28). Feedback to the user is provided by projection of an image (21,24) onto the surface or onto the original, or using some other visual display.

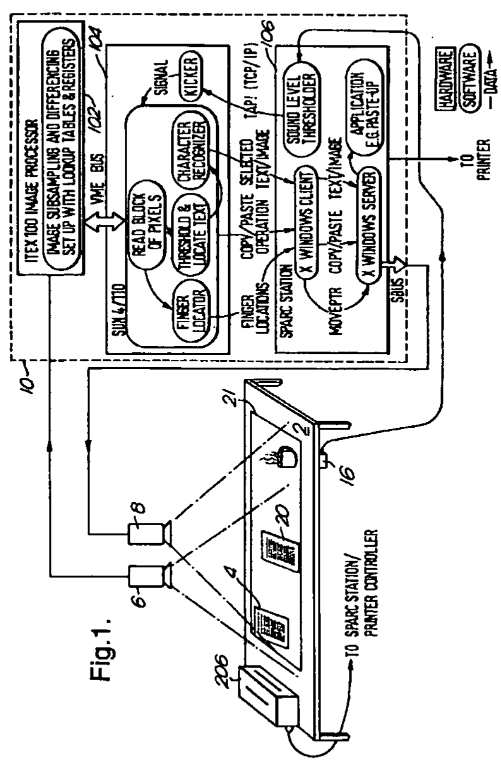


Fig.1.

EP 0 622 722 A2

The present invention relates to interactive image reproduction machines, and more particularly reproduction machines for performing various operations on text or images during the creation of a new document.

It is common for office workers and others who work with documents on a regular basis to have effectively two desks-the "electronic desktop" provided by a workstation or personal computer by means of a graphical interface, and the physical desk on which paper documents are received and processed.

The electronic desktop, which has become more and more like the physical one, can perform numerous useful operations on documents stored in electronic form; but in dealing with tangible documents such devices have limitations. A paper document must either be converted into electronic form before the operations are performed on it in the electronic environment, or copying operations are carried out on the tangible document using an electrophotographic copier (such as a photocopier with an editing function) or a combined scanning and printing device, the available functions of which are restricted in nature.

US-A-5,191,440 discloses a photocopier system for combining plural image segments taken from a series of different documents and printing the series of image segments as a composite image on a common copy sheet. The documents are sequentially scanned in, and the results of page creation and edit functions may be previewed on a display screen.

It is known from EP-A-495 622 to use a camera-projector arrangement positioned above a desk, in order to select functions to be performed by selecting items located within the field of view of the camera. Such functions include calculating and translating operations carried out on data [e.g., in a paper document] located on the desk.

The present invention seeks to reduce the abovementioned limitations on the operations which may be performed on data in a paper document, using interactive techniques in which the paper document effectively becomes part of the means for designating which operations (such as text/image selection, creation and manipulation) are carried out on the information contained in it, in order to create new documents using a processor-controlled copying or printing device.

It is an object of the present invention to provide an interactive copying system in which the available functions are expanded beyond both those provided by the conventional electronic environment alone, and those provided by existing copying equipment alone.

The present invention provides a copying system, comprising: a work surface; means for displaying images on the work surface; a camera, focussed on the work surface, for generating video signals representing in electronic form image information present within the field of view of the camera; processing means for recognising one or more manual operations relating to the image information which are executed by a user within the field of view of the camera, and for performing electronic operations, corresponding to said manual operation(s), on the electronic form to produce a modified electronic form; the displaying means being adapted to display, under the control of the processing means, simultaneously with or subsequent to said electronic operation performing step, images defined by said manual operations; and wherein said images defined by said manual operations include an image of the newly created document.

The copying system may further including a scanner, coupled to the processing means, for scanning a document containing said image information.

The system preferably further includes means, for sensing vibrational signals on the surface; the processing means being adapted to recognise a tap or strike by a user on the surface.

Preferably, the processing means includes a frame grabber, for storing video frames, and differencing means, for establishing the difference between pixel data values of corresponding pixels in successive video frames, and for displaying the resultant video frame data. Preferably, the processing means includes thresholding means, for converting multi-bit per pixel video frame data to 1 bit per pixel video frame data. Preferably, the thresholding means is adapted for carrying out said converting operation based on an estimate equal to the moving average of pixel intensities in a local area. Preferably, the local area comprises 1/nth of the width of a video frame, where n is preferably about 8.

Preferably, the processing means includes a frame grabber, for storing video frames, and means for calibrating positions in the frame grabber relative to positions within the display. Preferably, the calibrating means includes means for projecting a mark at four points in the display and carrying out said calibration by means of a four point mapping, given by

$$x' = c_1x + c_2y + c_3xy + c_4$$
$$y' = c_5x + c_6y + c_7xy + c_8,$$

where (x,y) is a point in the display (21) and (x',y') is a corresponding point in the video frame stored in the frame grabber.

The processing means may further include means for determining whether the user is right- or left-handed.

The present invention further provides a method of generating documents, comprising: providing a work surface, means for displaying images on the work surface, and a camera focussed on the work surface, said camera generating video signals representing in electronic form image information present within the field of view of the camera; recognising one or more manual operations relating to the image in-

formation which are executed by a user within the field of view of the camera; performing electronic operations, corresponding to said manual operation(s), on the electronic form to produce a modified electronic form; displaying, simultaneously with or subsequent to said electronic operation performing step, images defined by said manual operation(s); and wherein said images defined by said manual operations include an image of a newly created document.

The manual operation(s) may include designating a plurality of the extremities of a shape encompassing said selected portion of text or image information.

Preferably, the images defined by said manual operation(s) include an outline of, or a shaded area coincident with, said shape. Preferably, the shape is a rectangle.

The manual operation(s) may include pointing with a plurality of fingers at the corners of said shape.

Alternatively, said extremities are designated using a stylus in association with a position sensing tablet on the surface.

The manual operation(s) may include designating a text or image unit in the document by pointing a finger at it. The manual operation(s) may include designating a successively larger text or image unit in the document by tapping on the surface. The manual operation(s) include confirming a text or image selection by tapping on the surface. The manual operation(s) may include copying the selected text or image to a location in a new document displayed on the surface by pointing at the selected text or image using a finger or stylus and dragging the finger or stylus across the surface to said location in the new document, and dropping the selected text or image at said location by tapping on the surface. The manual operation(s) may include changing the dimensions of selected text or image by changing the separation of finger tips of the user defining extremities of the selected text or image. The manual operation(s) include placing paper signs within the field of view of the camera, the signs defining operations to be performed on selected text or image information.

The invention further provides a programmable copying apparatus when suitably programmed for carrying out the method of any of claims 4 to 7, or any of the above described particular embodiments.

The present invention further provides a copying system according to claim 9 of the appended claims.

The copying system may further including means for scanning the second document to generate an electronic version of the second document; wherein the processing means includes means for recognising the positions of the transferred image information in said electronic version; the system further including means for printing said transferred image information on said second document.

The present invention further provides an interactive image reproduction system, comprising: a plurality of workstations interconnected by a communications link, each workstation comprising a copying system according to any of claims 1 to 3, 8 or 9, each workstation being adapted for displaying the video output from the camera of the or each other workstation. The system may further include an audio or videoconferencing link between the workstations.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram of a copying system according to the invention;

Fig. 2 shows schematically a known imaging system into which the system of Fig. 1 may be incorporated;

Fig. 3 illustrates an image generated in the finger-tracking technique employed in the present invention;

Fig. 4 shows a four point mapping technique employed by the present invention;

Fig. 5 illustrates four ways to sweep out a selection rectangle when using the present invention;

Figs 6(a) to (f) show successive scenes of the desk surface in a copying operation according to one embodiment of the invention;

Fig. 7 is a flow chart of the procedure of Fig. 6;

Figs. 8(a) to (e) illustrate successive scenes of the desk surface in a copying operation according to a second embodiment of the invention;

Fig. 9 is a flow chart of the procedure of Fig. 8;

Figs. 10(a) to (h) show successive scenes of the desk surface in a copying operation according to a third embodiment of the invention;

Fig. 11 is a flow chart of the procedure of Fig. 10;

Fig. 12 shows a view from above of the desk surface during a copying operation according to a fourth embodiment of the invention;

Fig. 13 is a flow chart of the procedure of Fig. 12;

Fig. 14 shows a view from above of the desk surface during a copying operation according to a fifth embodiment of the invention; and

Fig. 15 is a flow chart of the procedure of Fig. 14.

Referring to Fig. 1, this illustrates schematically the copying system of the present invention. A flat desk surface 2 has placed on it a document 4 to be used as a source if textual or graphical information during manipulations which are described in detail below. The document 4 is located within the field of view of a video camera 6 mounted above the desk surface 2. A video projector 8 is mounted adjacent the camera 6 and projects onto the surface 2 a display 21 which is generally coincident with the field of view of the camera 6, and which, in the example shown, includes an image of a newly created document 20, as discussed below. The camera 6 and the projector 8 are both connected to a signal processing system, generally designated 10, which is in turn connected

to a printing device 208 and, optionally, a document scanner 206 (see Fig. 2). A small snare-drum microphone 16 (preferably with built in amplifier) is attached to the bottom of the desk and picks up audible or vibrational signals. The system 10 monitors the (digitised) signal amplitude of the microphone 16 to determine (e.g. by comparison with a threshold value) when the user taps on the desk 2 (e.g. to designate an operation (see below)).

The architecture of the signal processing system 10 is schematically illustrated in Fig. 1. This implementation runs on standard X Window applications using the human finger as a pointing device. The system is implemented so that finger tip location and desk tapping information are sent through X in such a way that from the point of view of applications, these events are indistinguishable from those of a conventionally-used mouse. The system runs on two machines: a Sun 4/110 (104) and a SPARCstation (106). This is because the image processing board 102 plugs into a VME bus, while the projected video (LCD) display plugs into an Sbus. The images captured by the camera 6 are initially processed by an Itex100 image processing board 102. Any other suitable architecture could be used to achieve the image signal handling. Figure 1 illustrates how the software modules interface to each other and to the hardware. The system is implemented in C + + and C under SunOS and TCP/IP.

The desk-camera-projector arrangement (2,6,8) may be located remotely from the printing device 208 and any number of such arrangements may be linked up to a common printer. Alternatively, the surface 2 may itself constitute an upper surface of a copying or printing machine, or the surface of a desk next to such a machine, with the advantage that any documents created using the system may be immediately printed out and taken away by the user. The processor 10 may form an integral part of a copying or printing machine, or may be remotely located in a separate device and coupled to the printer by a conventional communications link.

In a preferred embodiment, the system of Fig. 1 forms an integral part of a printing system, for example as schematically illustrated in Fig. 2 and described in detail in EP-A-592108, with the exception that appropriate elements of the control section 207 are replaced by hardware from Fig. 1, such as the user interface 252 (which is implemented by the camera-projector arrangement (6,8)), the system control 254, etc. For additional control detail, reference is made to US-A-s 5,081,494, 5,091,971 and 4,686,542.

Interacting with objects with bare fingers is facilitated in the present invention through video-based finger-tracking. A bare finger is too thick, however, to indicate small objects such as a single letter, for which a pen or other thin object is used.

The current implementation uses simple image processing hardware to achieve the desired interactive response time (although suitable algorithms could be used to achieve the same result): it initially subsamples the image and processes it at very low resolution to get an approximate location for the finger. Only then does the system scale to its full resolution in order to get a precise location, so only small portions of the image need to be processed. If the user moves too quickly, the system loses track of where the finger is, so it immediately zooms back out to find it. The result is that large, quick movements are followed less precisely than fine movements, but for pointing applications this seems acceptable.

Interaction techniques using video-based finger tracking, are demonstrated by M. Krueger (*Artificial Reality II*, Addison-Wesley, 1991). The disadvantages of his system are discussed in UK patent application 9313637.2 (hereafter Ref. 1), a copy of which was filed with the present application.

In contrast, the present invention senses motion (since most objects on the desk 2 do not move except the user's hands and the objects they are holding): it captures sequential video frames and examines the image produced by subtracting the sequential values of each pixel in two successive frames. The result for, e.g., a moving hand looks like Figure 3. Further processing is then carried out to remove noise and to locate the precise position of the fingertips.

Motion detection uses an image loop-back feature of the board 102 that allows the most significant bits of two images to be sent through a look-up table. This table is set up to subtract the two images, allowing very fast differencing of successive frames. Current finger-tracking performance using the Sun 4/110 and Itex100 image processing board 102 is 6-7 frames/sec.

Determining when the user taps on the desk is preferably achieved using the microphone 16. Another way to detect tapping is to use a touch screen, which can provide dragging information as well as extra location data.

Projection from above provides similar capabilities to a large flat display screen, but it has the key advantage that computer-generated images 21 can be superimposed onto paper documents. This is necessary for creating merged paper and electronic documents, and for providing feedback when making selections 22, 28, 31 (see below) on paper. Overhead projection, however, does produce problems, such as shadows: these are hardly noticed when the projector is mounted above a horizontal desk 2, but special measures must be taken to avoid shadow problems on a nearly vertical surface, if this is used as the work surface (like a drawing board).

The brightness of the room may affect the clarity of the projected display. This is not a problem with normal fluorescent lights, but a bright desk lamp or direct sunlight should be avoided. The area onto which

display 21 is projected should preferably be white.

In the implementations described herein the image output device may be any device that provides an image in the work surface: e.g. a CRT display conveyed to the surface 2 by means of mirror elements above or below the surface 2; or a flat panel LCD display integral with the desk and disposed either at the surface or below it. Any number of displays may be used.

Document images are captured through an overhead video camera 6, but a difficulty with standard video cameras is their low resolution (compared to scanners), which may not permit good quality copying from a document on the work surface. Several solutions are possible.

One technique is to use a very high resolution camera 6 for the system.

Another solution is to use multiple cameras. At least one camera 6 is set up with a wide field of view that encompasses the substantially the entire work surface 2. At least one other camera (hereafter-"subsidiary camera";not shown) is mounted adjacent the main camera 6 and zoomed in to cover a small part of the desk surface 2 (within or outside the display area 21) at high resolution (e.g. about 200 spots/inch; 8 spots/mm). Multiple fixed subsidiary cameras may be used to cover the whole area at high resolution, or fewer movable subsidiary cameras could be used. The video signal from each camera is processed via a respective channel of the image processing board 102, by means of suitable multiplexing techniques which are well known in the art. When such a subsidiary camera with a relatively small field of view is used, a light area (e.g. a white "window" or other visual indication such as a black rectangular outline) is projected onto the surface 2 so as to coincide with the field of view of the high resolution subsidiary camera(s) and indicate to the user exactly what part of the work surface is within that field of view (i.e., the active area). The user can therefore place source documents 4 within this high resolution "window" to enable text or image information to be scanned in by the system at high resolution. Since it has been found so far that only small parts of a document at a time need be used, and sliding a piece of paper into the camera's "window" is so easy, the use of multiple fixed cameras to cover the whole desk appears unnecessary.

A further possible technique solves this problem by storing information about the positions in the source document 4 of the part(s) to be copied, by means of image recognition techniques and the use of document descriptors. The document is then put through a (desktop) scanner 206 (or is pre-scanned before image manipulation takes place), preferably a high resolution (e.g. 24 dots/mm; 600 dots/inch) scanning machine, and this position information is used to determine what parts of the scanned image to use in the eventual copy. With this technique, the user interacts with the documents at the lower (camera) resolution, but the finished product is constructed from higher (scanner) resolution images. Prescanning is inconvenient for many interactive applications, however, so it is preferred to use one of the abovementioned alternative methods.

The image produced from a video camera 6 and frame grabber (not shown) on the board 102 is greyscale (typically eight bits/pixel). This grey-scale image must be thresholded, or converted to a one bit/pixel black and white image, before it can be used for character recognition or any of the other embodiments which are described herein.

Simple thresholding is not adequate for obtaining an image suitable for character recognition. Another problem can be automatic grey balancing on the camera. This can cause a change in brightness in one part of the image to affect the values in all other parts.

Consequently, the system uses an adaptive thresholding algorithm which varies the threshold value across the image according to its background value at each pixel. The present system produces results in a single pass which are nearly as good as systems requiring multiple passes through the image, by calculating the threshold value at each point from an estimate of the background illumination based on a moving average of local (within about 1/8th the width of the image) pixel intensities. This method is fast and can be combined with a scaling operation if necessary.

Finally, when dealing with text, the thresholded image is skew-corrected and recognised by an OCR server (in this case, Xerox Image System's ScanWorkX). If the resolution is high enough relative to the text size, then it returns the associated ASCII string. For accuracy, it is important to provide both quick feedback to the user (by displaying immediately the number or character which the system "thinks" it has recognised), and a simple way for the user to correct unrecognised characters.

To support interaction, projected feedback 24, 26 (see Fig.6) to the user, and selective grabbing of images through the camera 6, the system must map coordinates in the projected display 21 to coordinates in the frame grabber of image processor board 102. This calibration may be difficult because the projected display 21 is not a perfect rectangle (there are optical distortions such as "keystoning"), the camera 6 and/or tablet may be rotated relative to the projected display 21, and it may be necessary for the camera 6 to view the projected display from an angle. Also, vibrations caused by, e.g., air conditioners or slamming doors cause movements which disrupt the calibration, as do any adjustments to the equipment.

In the case where stylus input is used to indicate position on a tablet, the system first maps absolute positions on the digitising tablet to positions on the display 21 in order to provide feedback. Second, pos-

itions on the display 21 are mapped to corresponding positions in the frame grabber in order to support grabbing of selected areas 22, 28, 31 (see below) on the desk. Obtaining the data to calibrate the pointing device (stylus + tablet; touchscreen) to the display 21 is relatively straightforward: a series of points are displayed and the user is prompted to touch them with a pointer 32 (see Fig. 8).

In the case where position indication by finger tip location is used, obtaining data for calibrating the video camera 6 to the display 21 is not as simple.

Figure 4 shows an approach which improves on prior techniques: this is to project an object that can be located by the image processing system, allowing the system to self-calibrate without any assistance from the user. The present system projects a thick "plus" sign (+), and uses image morphology (see D. Bloomberg & P. Maragos, "Image Algebra and Morphological Image Processing", *SPIE Conference Procs,* San Diego, CA, July 1990) to pinpoint the centre of the mark in the frame grabber coordinate space.

For accurate mapping, preferably a four point calibration system (Fig. 4) is used, which compensates for rotation and keystoning. The mapping is given by the equations

$$x' = c_1x + c_2y + c_3xy + c_4 \quad (1)$$

$$y' = c_5x + c_6y + c_7xy + c_8 \quad (2)$$

where (x,y) are coordinates in the projected display, and (x',y') are coordinates in the frame grabber.

With four point pairs, the set of simultaneous linear equations can be quickly solved by Gaussian Elimination. Then, a fifth plus mark (+) is projected and its location is checked to make sure it is close enough to the position produced by the above mapping. The result is accurate to within one or two display pixels, allowing the user to select areas 22, 28, 31 on the desk 2 and rely on the displayed feedback 24 to precisely indicate what will appear in the grabbed image.

Unlike a traditional workstation, user interfaces on the present system must take account of handedness. If feedback 24 (see, e.g., Fig. 6) is projected to the lower left of the pointer 32 (finger, stylus), for example, then a right-handed person has no trouble seeing it, but a left-handed person does have trouble because it gets projected on the hand. Not only is feedback affected, but also the general layout of applications, and left-handed users are inconvenienced because it requires them to reach their arm farther than right-handed subjects, and their arms hide the paper 4 they are reading. The system's video camera 6 can see the user's hands, so it preferably recognises automatically which hand the user is pointing with, and then uses this information in implementing the interface during the following work session. A pop-up menu, for example, is preferably projected to the left of the pointer for a right-handed person, and to the right of the pointer for a left-handed person.

When pointing at paper with the present system, the camera 6 must be able to "see" the paper 4, and this means that fingers and other pointing devices 32 must be out of the way. However, new users do not seem to have much difficulty learning how to interact with the system in a way that keeps selections (22,28,31) visible. When sweeping out a rectangle 24 (for example in the Fig, 6 embodiment described below) there are four ways of doing this (see Fig. 5). If right-handed people use method ①, or if left-handed people use method ②, they obscure the selection. But users do not seem to repeat the mistake: in general, the system cannot see a selection (22, 28, 31) unless the user can see it too, and that seems easy for people to learn.

Selection feedback 24 can also play an important role in preventing obscuration. In the implementation discussed herein, the projected selection rectangle 24 floats slightly ahead of the pointer, so it is easy to avoid placing the pointer inside.

Selecting parts of a document to be copied

In Figs 6(a)-(f) a basic user interface technique made possible by the copying system of the present invention - the selection of parts of a paper document 4 directly on the paper itself while the system reads the image selected - is illustrated in successive scenes, viewed from above the desk surface 2. The user 18 is creating a new document (generally designated 20) within the projected display 21, and here the source document 4 is a book page. The user selects a figure 22 on the book page 4 by first touching his two index fingers together at the top right hand corner of the figure 22: the system recognises this as a gesture for starting a selection. As the user then moves his left hand index finger to the bottom left hand corner of the figure 22 (motion ③ in Fig.5), the system processor recognises the movement and causes the projector to display, as feedback to the user, a selection block 24 (here a rectangular outline; alternatively a grey rectangle) which increases in size until this movement ceases (Fig.6(a)). The user can see exactly what is encompassed by the selection block 24, and when this is as desired, the user taps on the desk to confirm the selection (the tap being interpreted by the processor as such confirmation). The processor obtains via the camera 6 information indicating the positions of the boundaries of the selection block 24 relative to the original document 4 and therefore the extent of part of the document which has been selected.

Next, the user puts his pointed finger on the page 4 in the selection block 24 and "drags" a projected image of the selection block 24 by moving his finger across the display 21 (the selection block 24 is displayed by the projector 8 for feedback and moves to follow the position of the moving finger tip), positions

it in the appropriate location in the document 20, and taps on the desk with a finger to confirm the positioning (Fig. 6(b)). The figure 22 is captured by the camera 6, thresholded by the processor and the stored form of the document 20 edited accordingly; and the result is that the projected display is modified so that the figure 22 is "pasted" into the document 20 at the desired location (Fig. 6(c)); here, the dimensions of the pasted-in figure 22 are adapted by the processor 10 to the available height and width of the text area of the new document 20.

It is then possible for the user to add a legend to the pasted-in figure 22 by typing out the text thereof on a conventional keyboard (not shown) linked to the processor 10. The stored electronic form of the document 20 is edited by the processor, and the projected display 21 is simultaneously modified to show the legend 26 (Fig. 6(d)) as it is typed in.

Next, the user selects a portion 28 of text from the book page 4 which is to be pasted in below the figure in document 20 (Fig. 6(e)). This is done in exactly the same way as selecting the figure 22 in Fig. 6(a), except that the user starts with both index fingers at the top left hand corner of the text portion 28 and moves his right hand index finger to the bottom right hand corner of the text portion 28 (motion ④ in Fig. 5). The text selection 28 is positioned in the document by tapping on the surface 2, as before. The difference in this case is that optical character recognition (OCR) is performed on the selected text portion 28 captured by the camera 6. The font of the text 28 is automatically converted into that of the rest of the electronic document 20, and is reformatted so as to fit into the text flow of the document 20 being made up. (Alternatively the text 28 could be treated in the same way as the figure 22 in Figs 6(a) to (c), by selecting from top right to bottom left: i.e. motion ③ in Fig.5.) The stored electronic form of the document 20 is updated accordingly by the processor 10 and the projector 8 automatically displays the modified document 20 (Fig.6(f)).

Once completed, the document 20 can be printed out by conveying to the processor 10 a command to send the electronic version of the document 20 to the printer 14. This command may be entered via the keyboard or conventional mouse operation, but is preferably designated by the user selecting an appropriate item from a pull-down menu (not shown) accessable, e.g. by finger pointing, in the display area 21 on the surface 2.

In an alternative implementation, the work surface 2 may incorporate a touch pad or other position sensing device; and the user can use an appropriate stylus to indicate corners of a rectangular selection block designating a part to be copied, such as by starting in one corner and moving the stylus to the opposite corner. (In this case, in order for the stylus and position-sensing tablet to operate, the document 4 must only be a single-sheet thick.) It is also possible to select non-rectangular regions by tracing a "lasso" around the part of the paper document to be copied. Another possibility is for the user to simply point at a region and the system can use image morphology techniques to determine the scope of the selection. One tap on the work surface could select only the smallest discernable element pointed to (e.g. a letter or word). Another tap in the same location would expand the selection to include the sentence containing that letter or word, a further tap causing selection of the paragraph containing that sentence, or larger visual unit, and so on. With all of these selection techniques, precise feedback is projected so the user can see exactly what is selected, and can therefore adjust the selection if it is not exactly what the user wants (e.g. selecting a "don't care" location - beyond the boundaries of the document 20 - whereupon the projected selection is cancelled; and then re-selecting from the source document).

Figure 7 illustrates, by means of a flow chart of appropriate software running in the signal processing system 10 of Fig. 1, the steps involved in carrying out the procedure sequentially illustrated in Fig. 6.

Copying onto marked document

Another basic technique made possible by the present invention is the copying onto a previously marked document in novel ways. For example, a form can be filled in with data from parts of one or more other documents.

This technique is illustrated in Figs 8(a) to (f), which show successive scenes, viewed from above the surface 2. The technique is similar to that used in the embodiment illustrated in Fig. 6, except that the document 20 consists of the information to be added to a marked document 30 (in this case a form) placed on the work surface 2. Operations are performed to indicate how the form 30 should be completed, producing a projected image showing the additional marks that are to be made on the document.

As illustrated in Fig.8(a), the source document 4 comprises a receipt positioned within the camera's field of view. The user selects the numerical total 31 indicated on the receipt using the above-mentioned stylus and position-sensing tablet method (but any of the above-mentioned image-selection techniques could be used). An image of the selected number, captured by the camera 6, is projected back onto the display 21 at the position of the point of the stylus 32. As the projected image of selected number is dragged to the appropriate box 34 of the form 30, in a similar way to the moving selection block 24 in the Fig.6 embodiment, the motion of the number is shown in the display by the projector 8 (Fig.8 (b)). The number is recognised by the processor 10 using OCR and dropped in the box 34 by releasing a button on the stylus, or by the user tapping on the desk with his free hand.

Figure 8(c) illustrates an operation performed in the case where the appropriate data is not present in the source document 4: the user writes a date in the appropriate box 36 of the form by hand. The movement of the point of the stylus 32 is tracked as the user writes, and an image is simultaneously projected down onto the form 30 showing the ink which would have been left on the form if the stylus were a pen. The system recognises the user's characters as they are written, converts the projected "ink" characters into the same font as the other numbers on the form 30 and modifies the projected characters to make them appear in that font. Once one entry (e.g. a date in numerical form) has been made in this way, it can be copied to other boxes in in the same or neighbouring column using the above-described drag and drop process, or even copied by making ditto signs by hand in the appropriate places.

Once the relevant numbers have been "entered" in the form 30, an operation can be performed on a group of numbers. In Fig.8(d) a column 38 containing a set of "entered" numbers is selected using the stylus 32. Next, the user places on the form 30 a small piece of paper having a button 39 printed on it and designated "SUM", with its arrow pointing at the interior of a box 40 on the form 30 in which a total is to be entered. When the user "presses" the paper button by tapping a finger on the piece of paper as shown in Fig. 8(e), the sum of the numbers in the selected column 38 is projected into the box 40. In doing this, the system (1) recognises the function of the button (e.g. by means of morph glyphs present in the drop shadow 42 of the button 39), (2) recognises the tapping of the button so as to be aware of where and when to perform the summing operation, (3) carries out the summing operation, and (4) projects the resulting numerical sum into the box 40.

When all the necessary entries have been made in the form 30, the latter can be fed through a printer 14 in order to make the projected marks permanent. [For this purpose it may be convenient, in the case where the main printer 14 is remote from the desk 2, to have an additional compact ink jet printer (not shown) on the desk surface 2, enabling the printing of the additional marks on the form and, if necessary, the signing of the form by a user, to be carried out immediately.] The processor 10, which stores the relative positions of all the projected characters and numbers with respect to the features of the form 30, causes the corresponding ink marks to be made in the appropriate locations (row/column/box) in the form during the printing operation.

Figure 9 illustrates, by means of a flow chart of appropriate software running in the signal processing system 10 of Fig. 1, the steps involved in carrying out the procedure sequentially illustrated in Fig. 8.

This technique is preferably extended by performing OCR on a selection from a source document 4 and then projecting the recognised numbers or characters in image to fill in a form or other pre-marked document. In general, text selections are discriminated from graphics selections and OCR performed, where necessary. Optionally, a user may select a location on a form 30 using one of the above-described techniques, and then type characters into the projected image with a conventional keyboard (not shown) linked to the processor 10.

The above-mentioned paper buttons may also be used to extend this technique: various buttons displaying appropriate recognisable codes (as mentioned above) are used to perform commonly executed operations, such as currency conversions, averaging etc.

This technique further includes recognising other tools and modifying the projected image appropriately. When a stylus is used as a marking tool, and moved across the surface (e.g. for handwriting), a mark is produced in the image. If the resulting marks meet some criterion, recognition is performed and the marks replaced by the appropriate characters or numbers. Also, an eraser is recognised similarly and, in addition to its physical erasure of marks, the projected image is modified appropriately.

If a paper form is recognised by the system, then it can assist the user with prompts as to how to fill it out, and it can perform calculations (e.g. adding a column of numbers) that are specified on the form. In general, the system can augment any recognisable paper form with features now available only with electronic forms.

Scaling and positioning document parts in projected image

Another user interface technique made possible by the present invention is scaling or positioning parts of a document before copying. In this disclosure, the term "arrange" is used generally to include an operation that scales (re-sizes) a document part, an operation that positions a document part, or an operation that both scales and positions a document part. Position of a document part also includes orientation. The basic technique for arranging a document part is to perform arranging operations in the projected image. In other words, a user can provide signals through the camera requesting operations so that the document part appears at a different scale or different position in the projected image. In effect, the user changes the projected image until it shows a desired final, output document with the indicated document part scaled and positioned as desired. The output document can then be printed.

To perform scaling, the user can indicate a different spacing between the opposite corners of a document part bounded by a selection rectangle, such as by moving the fingertips together or apart. Scale of

the selected part in the projected image can then be changed in proportion to the change in spacing.

To perform selection and positioning, the user proceeds as in the embodiments of Figs 6 and 8, except as mentioned below.

Figure 10 illustrates this technique: successive scenes, viewed from above the surface 2, show how the invention is employed by a user in producing a sketch.

Initially, the user sketches out a scene using an ordinary pencil and which includes a tree 46 (Fig. 10(a)). Next, the user, desiring to create a row of trees, selects the image of the tree 46 by sweeping out a selection block 24 in the same manner as described with reference to the Fig.6 embodiment (Fig. 10(b)). The user then moves a copy of the selection block 24 as in the Fig.6 embodiment, except that two fingers (or finger and thumb) are used which, when the copied block 24 is in the desired position, are used to reduces the size of the block to the desired scale (Fig. 10(c)). The user taps on the desk surface 2 to "drop" the reduced tree 48 in position, and the projector displays the new tree 48 spaced apart from the original 46. This process is repeated three more times with the user's fingers progressively closer together, to produce a row of trees (46-54) in perspective along the lane 56 (Fig. 10(d)).

Next, the user begins to draw some slates 58 on the roof 60 of the house 62 (Fig. 10(e)). In order to save time the user places a paper button 64 designated "FILL" with its arrow pointing at the roof 60. The code in the drop shadow 66 of the button 64 is captured by the camera 6 and the command is recognised by the processor 10; similarly, the slate pattern 58 is captured when the user taps on the button 64. The user then moves the button 64 to the empty region of the roof and taps on the button again; and the system executes the button command by replicating the slate pattern 58 to fill the area within the boundaries of the roof 60 (Fig.10(f)). The resulting pattern is displayed by the projector 8.

A further step is illustrated by Figs 10(g) and (h): the user decides to include a window 66 in the roof 60, so some of the slate pattern must be erased. An "eraser" 68 having on it a printed sticker 70 displaying a code, similar to that on the above-mentioned paper buttons (39, 64), by means of which the system recognises the implement as an eraser. As the user sweeps out an area with the "eraser" 68, the erasing motion is recognised by the system, and the displayed pattern 58 is modified so as to omit the slate pattern from that area Fig. 10(g)). The user then draws in the dormer window 66 by hand Fig. 10(h)).

The result of these operations is a merged physical and electronically projected sketch similar to the combined form described in the Fig. 8 embodiment. Again, in order to make the projected marks (e.g. trees 48-54 and the slate pattern 58) permanent, the sheet 30 containing the sketch would be passed through a printer connected to the processor 10. The processor, which stores the relative positions of all the projected images with respect to either the features of the sketch or the boundaries of the sheet 30, causes the corresponding ink marks to be made in the appropriate locations on the sheet 30 during the printing operation.

Figure 11 illustrates, by means of a flow chart of appropriate software running in the signal processing system 10 of Fig. 1, the steps involved in carrying out the procedure sequentially illustrated in Fig. 10.

Another possibility for rotating and positioning parts of a source document 4 in the projected image is to move a paper original, for example containing image elements to be included in the final sketch, into the desired position within the projected document 20, and to select the image element of interest (e.g. by tapping on the surface 2) to be "pasted down" in place. This natural interaction technique allows any printed or hand-drawn image to be used as a sort of rubber stamp and advantageously allows the user to try an image element in various positions without having to produce a new complete sketch each time.

Random copying of document parts

The above basic techniques are especially powerful when considered together with the possibility of randomly copying from a set of input documents 4 to produce output documents. This user interface technique is based on obtaining information indicating the relationship between the input documents 4 and the output documents.

One way to obtain this information is to operate on the documents in sequence. In other words, the output documents include parts from input documents 4 in sequence, so that the input documents can be copied in order into the output documents. This can be inconvenient, however, such as when one of the input documents 4 include different parts that are copied into several of the output documents.

Another way to obtain this information without operating on the documents 4 in sequence is to use document recognition techniques. This is similar to the previous way except that it is unnecessary to provide identifiers on the documents. Instead, a document characteristic that can be detected at low resolution, such as line length pattern, can be used to obtain identifiers that are very likely to be unique for each document. Document classification techniques are described briefly in EP-A-495 622.

"Select and Paste" (or "Copy and Paste")

Although selecting text or images from one document, and "pasting" the selection into a second document is now a standard feature when manipulating

electronic documents, the same operation is awkward to perform with real paper, requiring a photocopier, scissors, and some glue or tape. The system of the present invention, however, makes it possible to select and paste paper documents 4 in the same way that we select and paste electronic documents. In this implementation, a sketch 80 on paper 4 can be electronically selected by sweeping out an area 24 of the paper (e.g. with a stylus 32) in a similar manner to that described above. When the stylus 32 is raised, the system snaps a picture of the selection 80, and the projected rectangle 24 is replaced by a thesholded electronic copy of the area. This copy can then be moved about and copied to other parts 82 of the paper 4 as described in the aforementioned application. Sliding this electronically projected copy over the drawing to place it somewhere else is very similar to sliding a paper copy (see Fig. 12).

In Fig. 12, the user has selected the sketch 80 of the window on the sheet 4, and has made two copies of it (82). Now he has moved and is about to "paste down" a copy 86 of the flower 84 that he drew.

Figure 13 illustrates, by means of a flow chart of appropriate software running in the signal processing system 10 of Fig. 1, the steps involved in carrying out the procedure illustrated in Fig. 12.

User testing revealed another way of using this tool which is also very powerful. Instead of constructing a mixed paper and projected drawing, it has been found that a user can construct a purely projected drawing from selected portions taken from any number of their paper sketches. The user can sketch a figure on paper, move it to the desired location in the projected drawing, then select it using the above-mentioned techniques so that it remains "pasted down" in that location even after moving the paper away. The effect is like that of dry-transfer lettering or "rubber stamping", but in this case from any piece of paper onto a projected drawing. This interaction technique is quite different from the standard "copy and paste" found on most workstations and takes advantage of unique qualities of the present invention: using both hands for manipulating and pointing as well as the superimposition of paper and electronic objects.

Multi-user systems

People often use documents when working together, and they often need simultaneously to see and modify these documents. Physical paper is normally constrained in that it cannot be written on, pointed to, or otherwise manipulated by two people simultaneously who are, for example, located on separate continents; but this constraint can also be addressed by the present invention.

Shared editing of documents has been disclosed in, e.g. J.S. Olsen et al., "Concurrent editing: the group's interface" in D. Daiper *et al.* (eds) *Human Computer Interaction - Interact '90,* pp. 835-840, Elsevier, Amsterdam). Most of this work has concentrated on screen-based documents, but the multi-user implementation of the present invention makes it possible to share real *paper* documents. It allows users in (at least) two separate locations to "share" their physical desks, by enabling both users to see and to edit each other's paper documents 4.

Referring to Fig. 14, in the case of a two-user system, the two processors 10 are connected by means of a conventional communications link. Each installation continuously grabs images 88 from its local desk 2 and projects thresholded images 90 from the remote desk 2'. The result is that both users see what is on both desks. When a paper document 4 is placed on a desk 2 of user A, it is projected onto desk 2' of user B and vice versa. The projections are digitally scaled and positioned to provide What You See Is What I See (WYSIWIS), and both users can draw (using a real pen 92, 92') on either paper documents 4 or on virtual documents. On both sides, the remote user B will see the new drawing projected in the corresponding place. Hand motions are also transmitted over the communications link and displayed, so if a user points to a certain place on a document 4 the other user can see this. (The partner's hands block the view of what is underneath them, just as with an ordinary desk, so this must be dealt with through social protocols and speech: not pictured in Fig. 12 is an audio link through telephones or speakerphones which is preferably provided to facilitate this. Another useful and even more preferable addition is a face-to-face audio-visual link.)

In Fig. 14, the local user A is drawing a "X" 88 on a paper sheet 4 in ink, while the remote user's (B) paper and hand can be seen having just finished drawing a "O" 90.

Figure 15 illustrates, by means of a flow chart of appropriate software running in the signal processing system 10 of Fig 1, the steps involved in carrying out the procedure illustrated in Fig. 14.

Claims

1. A copying system, comprising:
   a work surface (2);
   means (8) for displaying images on the work surface;
   a camera (6), focussed on the work surface, for generating video signals representing in electronic form image information present within the field of view of the camera;
   processing means (10) for recognising one or more manual operations relating to the image information which are executed by a user within the field of view of the camera, and for per-

forming electronic operations, corresponding to said manual operation(s), on the electronic form to produce a modified electronic form;

the displaying means (8) being adapted to display, under the control of the processing means (10), simultaneously with or subsequent to said electronic operation performing step, images defined by said manual operations; and

wherein said images defined by said manual operations include an image of the newly created document.

2. The copying system according to claim 1, wherein the modified electronic form includes an electronic version of a newly created document.

3. The copying system according to claim 2, further including means (208) for printing a document corresponding to at least part of said modified electronic form.

4. A method of generating documents, comprising:

providing a work surface, means for displaying images on the work surface, and a camera focussed on the work surface, said camera generating video signals representing in electronic form image information present within the field of view of the camera;

recognising one or more manual operations relating to the image information which are executed by a user within the field of view of the camera;

performing electronic operations, corresponding to said manual operation(s), on the electronic form to produce a modified electronic form;

displaying, simultaneously with or subsequent to said electronic operation performing step, images defined by said manual operation(s); and

wherein said images defined by said manual operations includes an image of the newly created document.

5. The method according to claim 4, wherein the modified electronic form includes an electronic version of a newly created document.

6. The method according to claim 4 or 5, further including the step of supplying to a printing device said electronic version; and printing out said newly created document.

7. The method according to claim 6, wherein said manual operation(s) include selecting a portion of text or image information in a document (4) located within the field of view of the camera.

8. A programmable printing apparatus when suitably programmed for carrying out the method of any of claims 4 to 7.

9. A copying system, comprising:

a work surface (2);

means (8) for displaying images on the work surface;

a camera (6), focussed on the work surface, for generating video signals representing in electronic form image information present in at least first and second documents within the field of view of the camera;

processing means (10) for recognising one or more manual operation(s) which are executed by a user within the field of view of the camera and represent the transfer of image information from the first document to the second document, and for performing electronic operations, corresponding to said manual operation(s), on the electronic form of said second document to produce a modified electronic form;

the displaying means (8) being adapted to display, under the control of the processing means (10), simultaneously with or subsequent to said electronic operation performing step, images defined by said manual operations.

10. An interactive image reproduction system, comprising:

a plurality of workstations interconnected by a communications link, each workstation comprising a system according to any of claims 1 to 3, 8 or 9, each workstation being adapted for displaying the video output from the camera (6) of the or each other workstation.

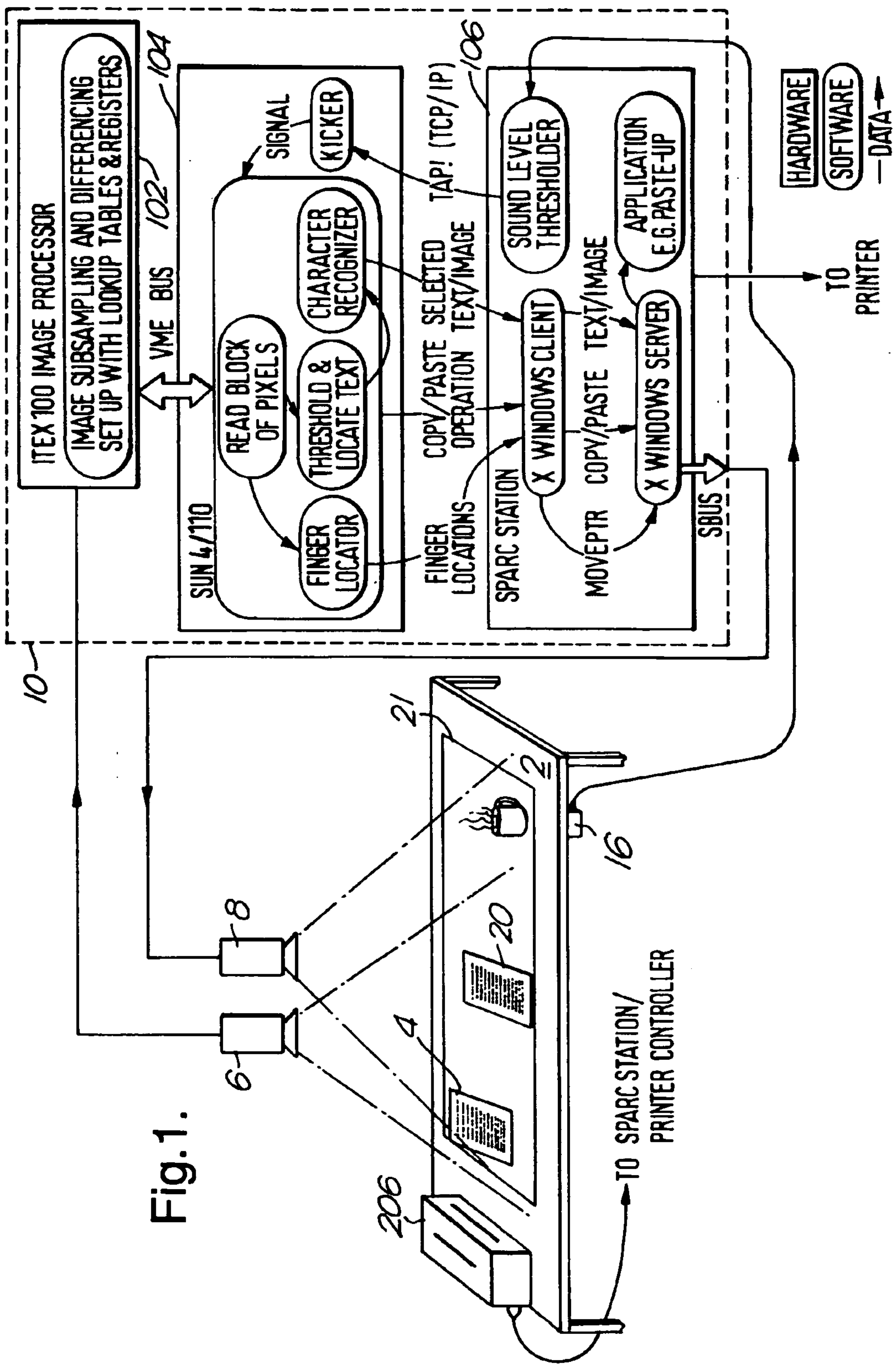

ITEX 100 IMAGE PROCESSOR
IMAGE SUBSAMPLING AND DIFFERENCING SET UP WITH LOOKUP TABLES &REGISTERS
102
104
VME BUS
SUN 4/110
READ BLOCK OF PIXELS
THRESHOLD & LOCATE TEXT
CHARACTER RECOGNIZER
FINGER LOCATOR
SIGNAL
KICKER
FINGER LOCATIONS
COPY/PASTE SELECTED OPERATION TEXT/IMAGE
TAP! (TCP/IP)
106
SPARC STATION
X WINDOWS CLIENT
COPY/PASTE TEXT/IMAGE
X WINDOWS SERVER
MOVEPTR
SOUND LEVEL THRESHOLDER
APPLICATION E.G.PASTE-UP
SBUS
TO PRINTER
HARDWARE
SOFTWARE
DATA
10
8
6
4
20
21
2
16
206
TO SPARC STATION/ PRINTER CONTROLLER

Fig.1.

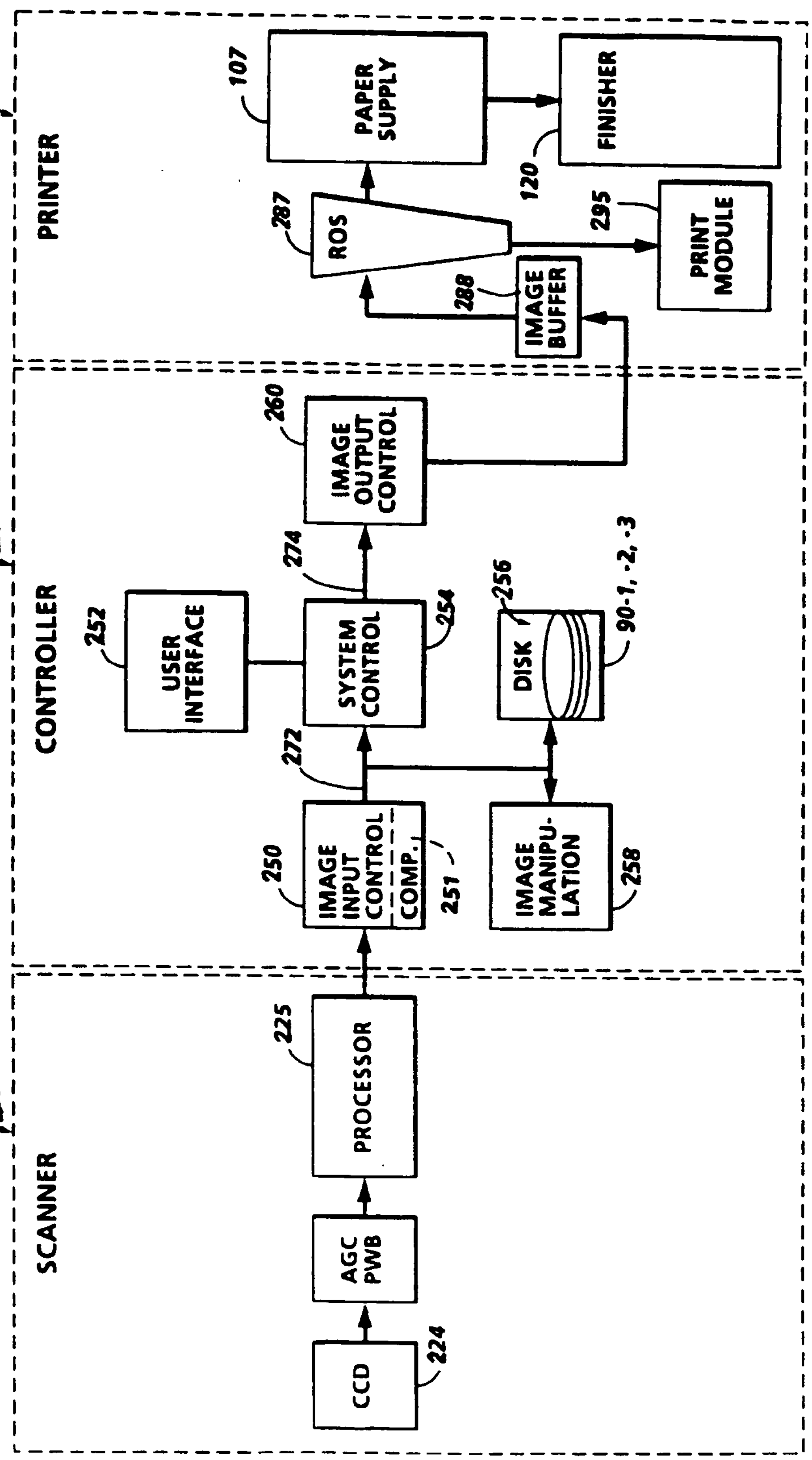

PRINTER
228
107
PAPER SUPPLY
FINISHER
120
287
ROS
288
IMAGE BUFFER
295
PRINT MODULE
CONTROLLER
207
260
IMAGE OUTPUT CONTROL
274
252
USER INTERFACE
SYSTEM CONTROL
254
256
DISK
90-1, -2, -3
272
250
IMAGE INPUT CONTROL
COMP.
251
IMAGE MANIPULATION
258
SCANNER
206
225
PROCESSOR
AGC PWB
CCD
224

Fig.2.

Fig.3.

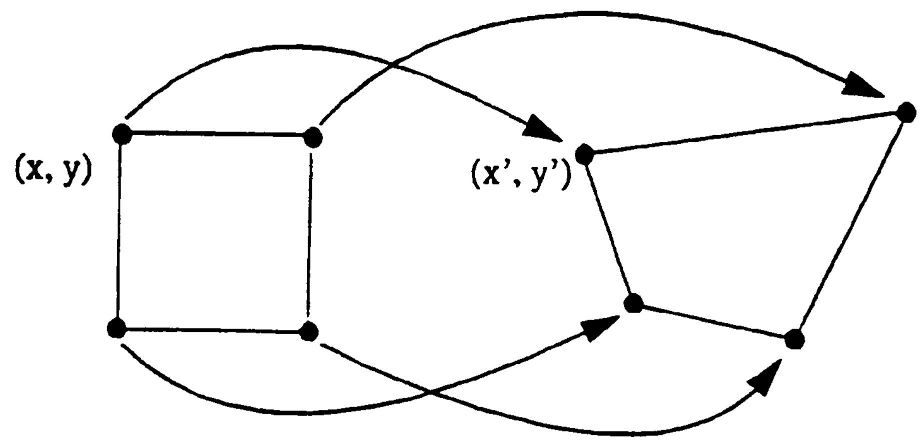


Fig.4.

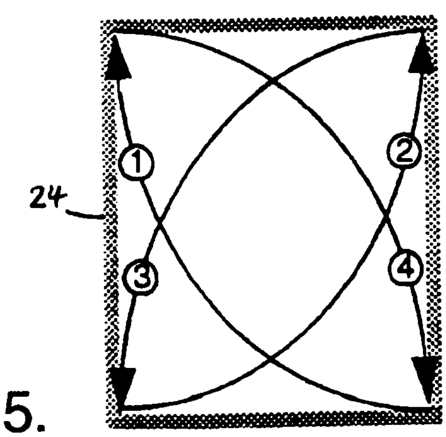


Fig.5.

Fig.6a

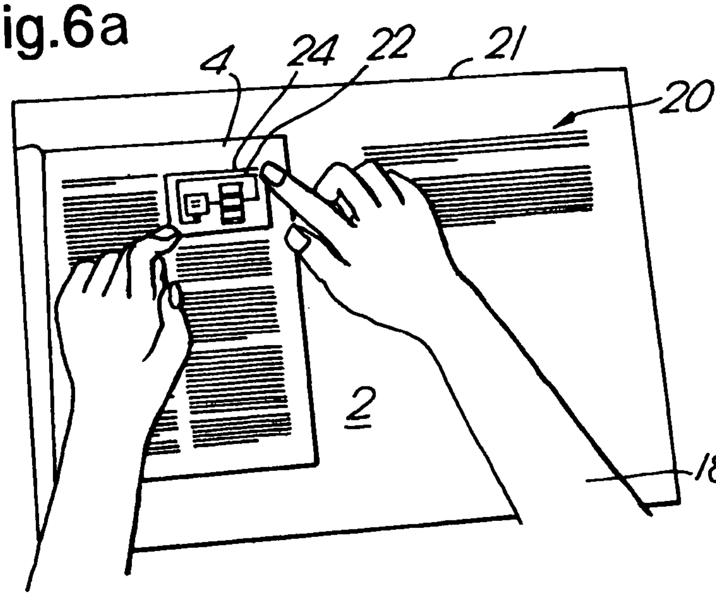


Fig.6b

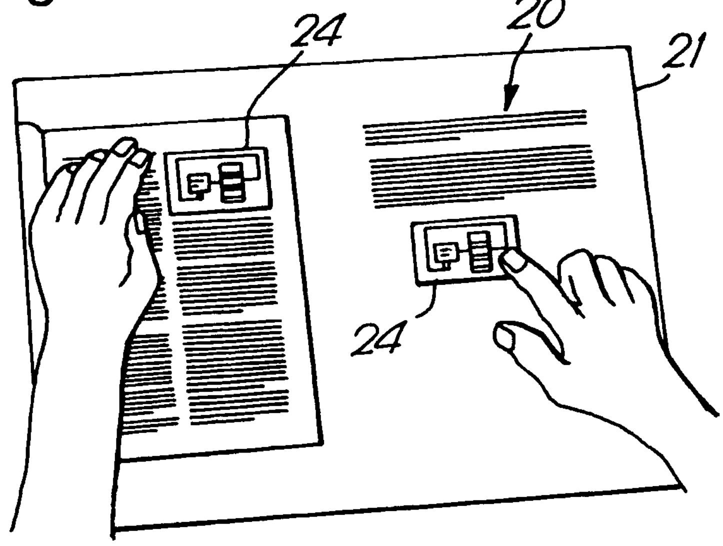


Fig.6c

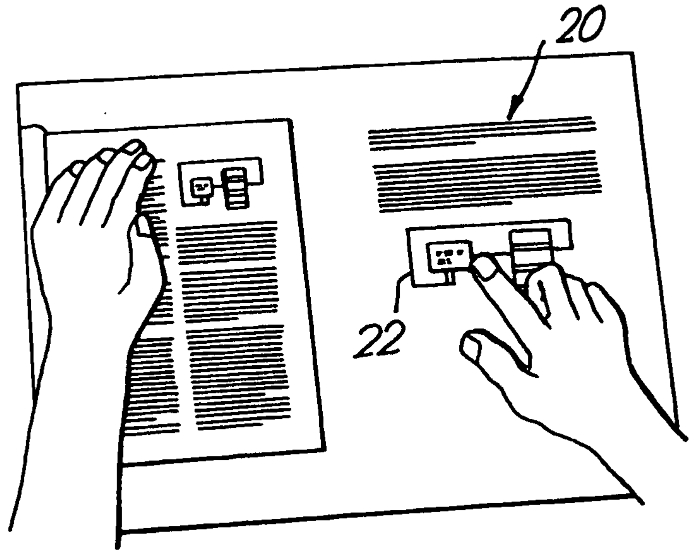


Fig.6d

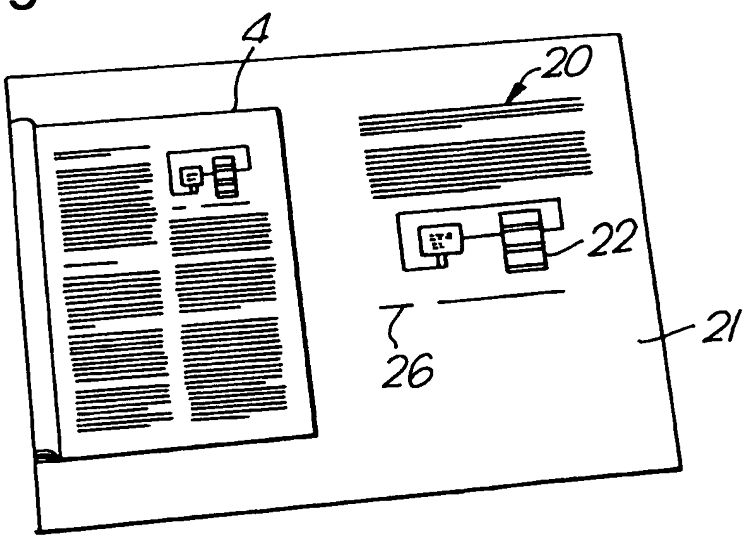


Fig.6e

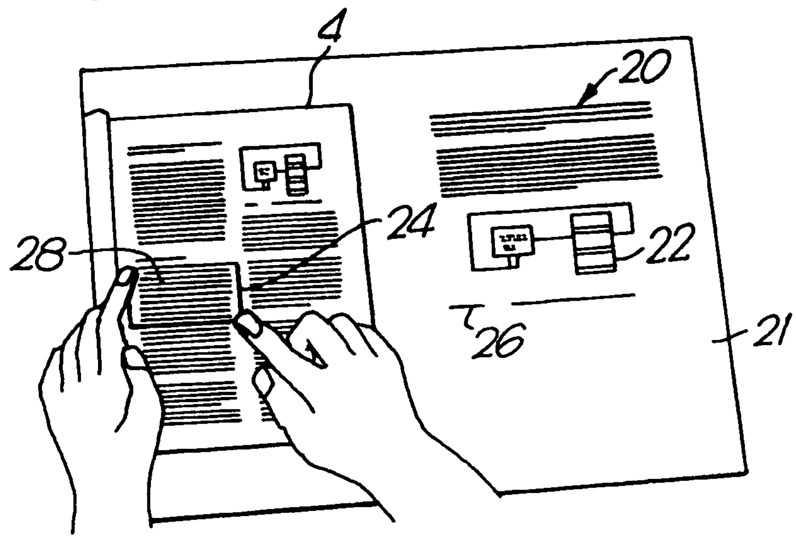
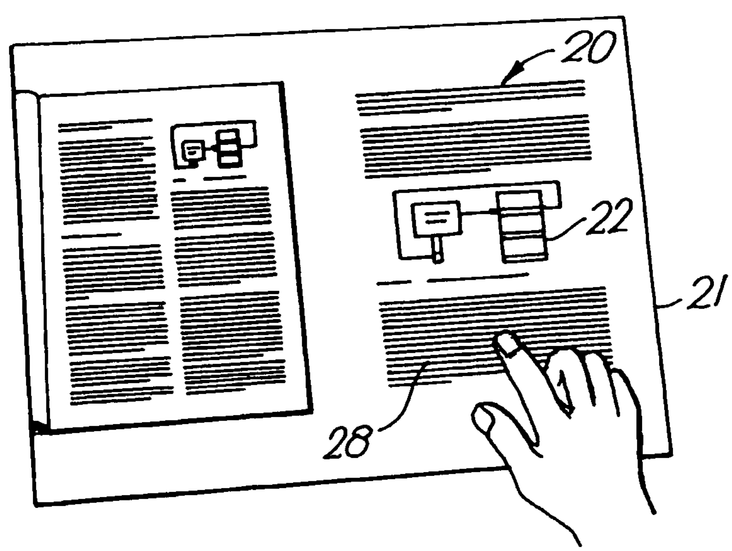


Fig.6f



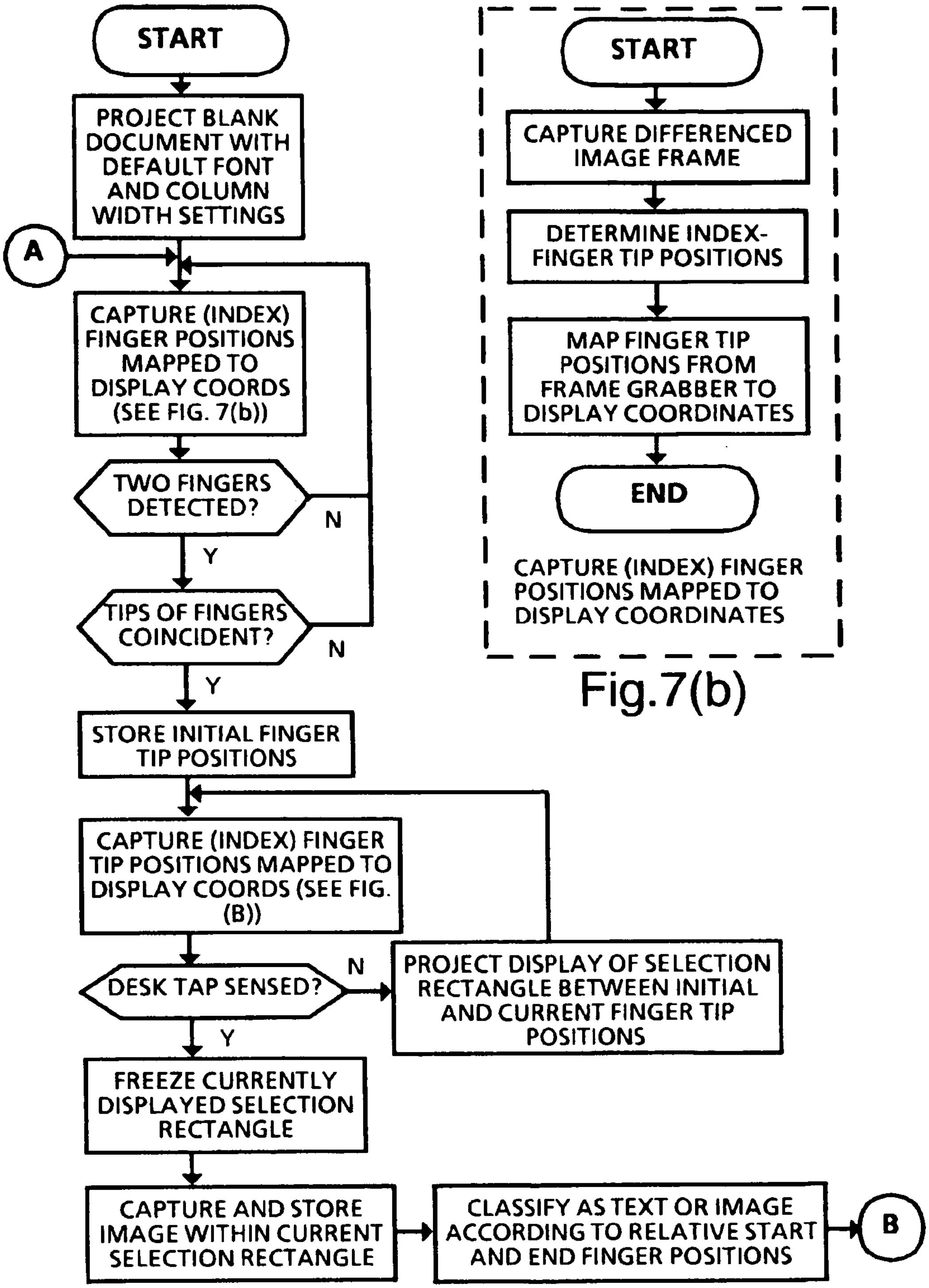

START
CAPTURE DIFFERENCED IMAGE FRAME
DETERMINE INDEX-FINGER TIP POSITIONS
MAP FINGER TIP POSITIONS FROM FRAME GRABBER TO DISPLAY COORDINATES
END
CAPTURE (INDEX) FINGER POSITIONS MAPPED TO DISPLAY COORDINATES
Fig.7(b)
START
PROJECT BLANK DOCUMENT WITH DEFAULT FONT AND COLUMN WIDTH SETTINGS
A
CAPTURE (INDEX) FINGER POSITIONS MAPPED TO DISPLAY COORDS (SEE FIG. 7(b))
TWO FINGERS DETECTED?
N
Y
TIPS OF FINGERS COINCIDENT?
N
Y
STORE INITIAL FINGER TIP POSITIONS
CAPTURE (INDEX) FINGER TIP POSITIONS MAPPED TO DISPLAY COORDS (SEE FIG. (B))
DESK TAP SENSED?
N
PROJECT DISPLAY OF SELECTION RECTANGLE BETWEEN INITIAL AND CURRENT FINGER TIP POSITIONS
Y
FREEZE CURRENTLY DISPLAYED SELECTION RECTANGLE
CAPTURE AND STORE IMAGE WITHIN CURRENT SELECTION RECTANGLE
CLASSIFY AS TEXT OR IMAGE ACCORDING TO RELATIVE START AND END FINGER POSITIONS
B

Fig.7(a)

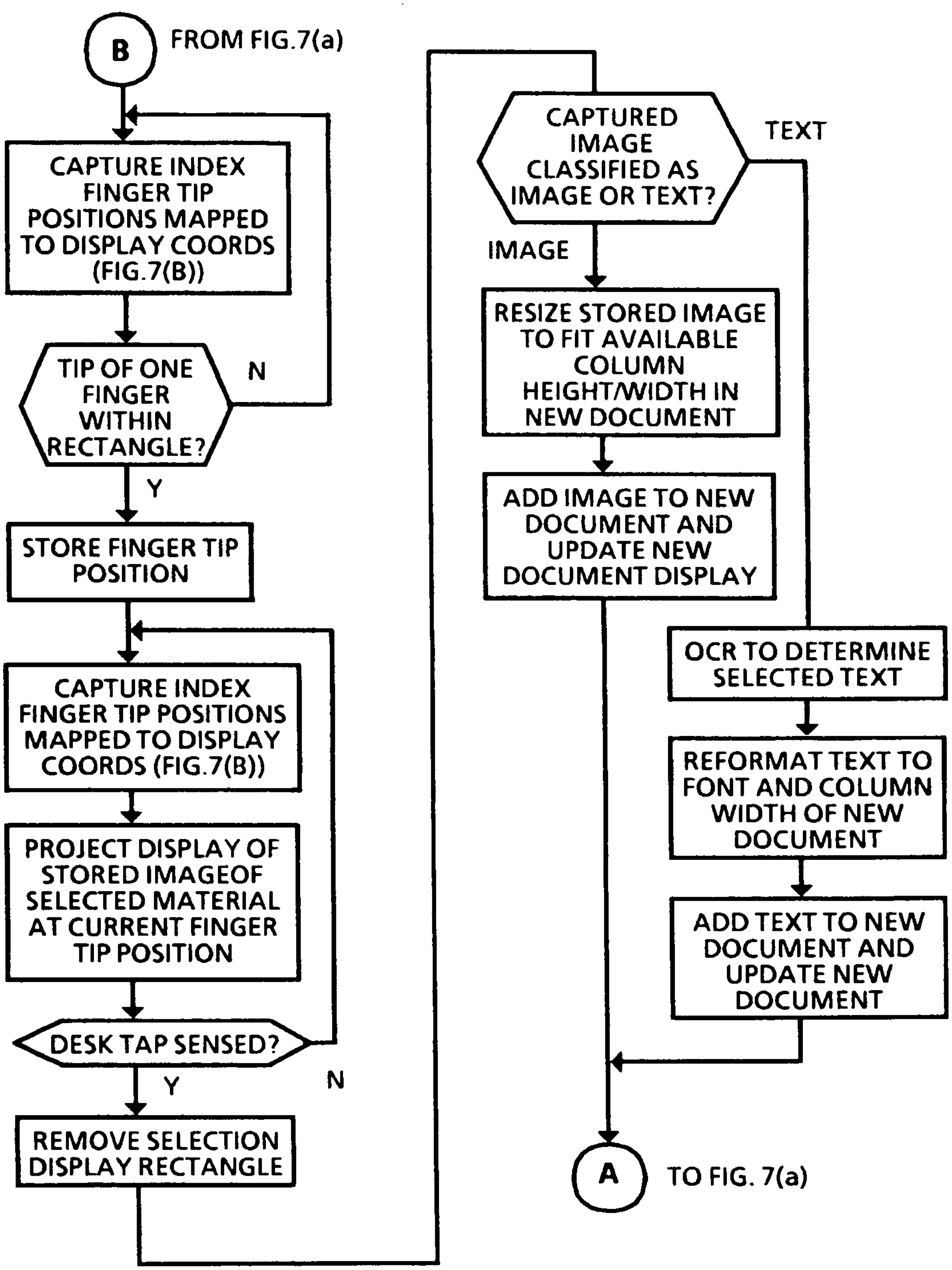

B
FROM FIG.7(a)
CAPTURE INDEX FINGER TIP POSITIONS MAPPED TO DISPLAY COORDS (FIG.7(B))
TIP OF ONE FINGER WITHIN RECTANGLE?
N
Y
STORE FINGER TIP POSITION
CAPTURE INDEX FINGER TIP POSITIONS MAPPED TO DISPLAY COORDS (FIG.7(B))
PROJECT DISPLAY OF STORED IMAGEOF SELECTED MATERIAL AT CURRENT FINGER TIP POSITION
DESK TAP SENSED?
Y
N
REMOVE SELECTION DISPLAY RECTANGLE
CAPTURED IMAGE CLASSIFIED AS IMAGE OR TEXT?
TEXT
IMAGE
RESIZE STORED IMAGE TO FIT AVAILABLE COLUMN HEIGHT/WIDTH IN NEW DOCUMENT
ADD IMAGE TO NEW DOCUMENT AND UPDATE NEW DOCUMENT DISPLAY
OCR TO DETERMINE SELECTED TEXT
REFORMAT TEXT TO FONT AND COLUMN WIDTH OF NEW DOCUMENT
ADD TEXT TO NEW DOCUMENT AND UPDATE NEW DOCUMENT
A
TO FIG. 7(a)

Fig.7(c).

Fig.8a

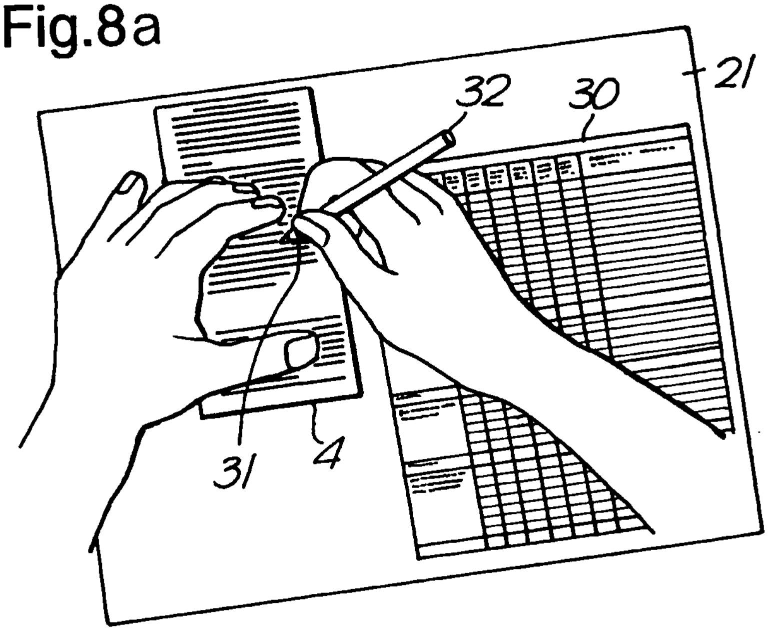


Fig.8b

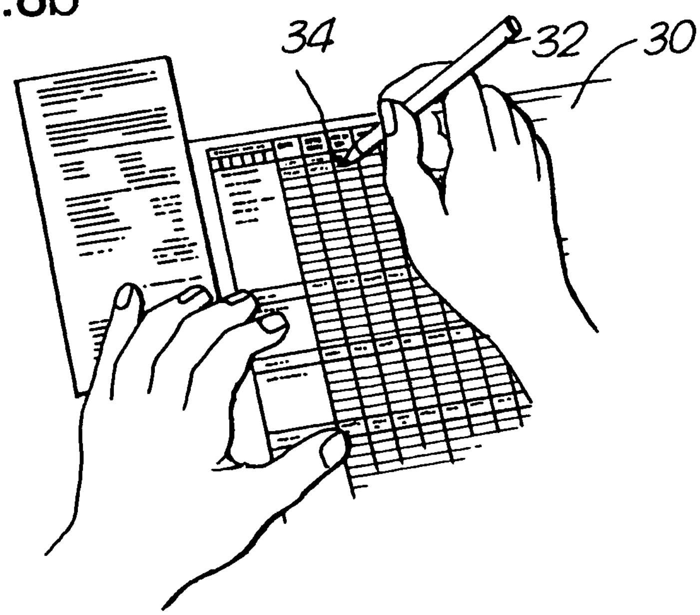


Fig.8c

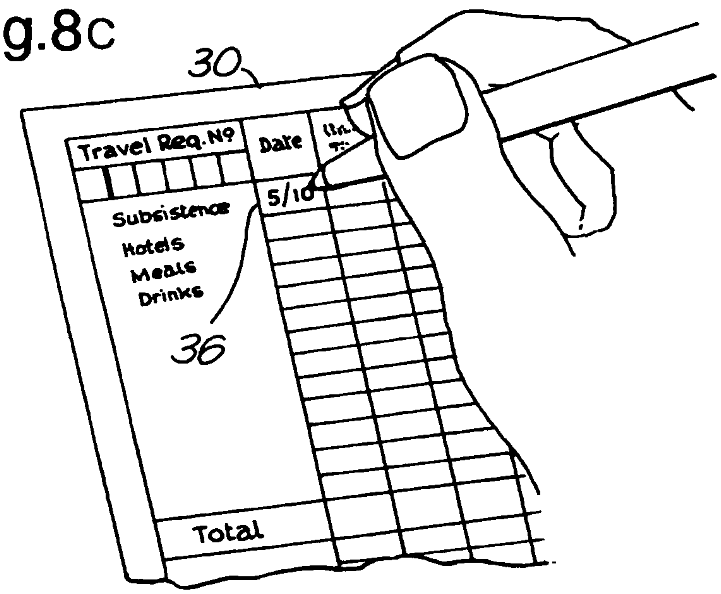

30
Travel Req.No
Date
5/10
Subsistence
Hotels
Meals
Drinks
36
Total

Fig.8d

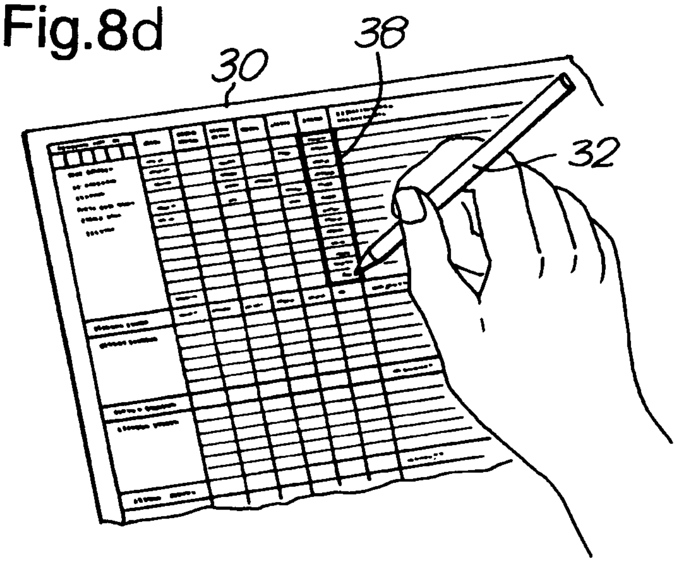
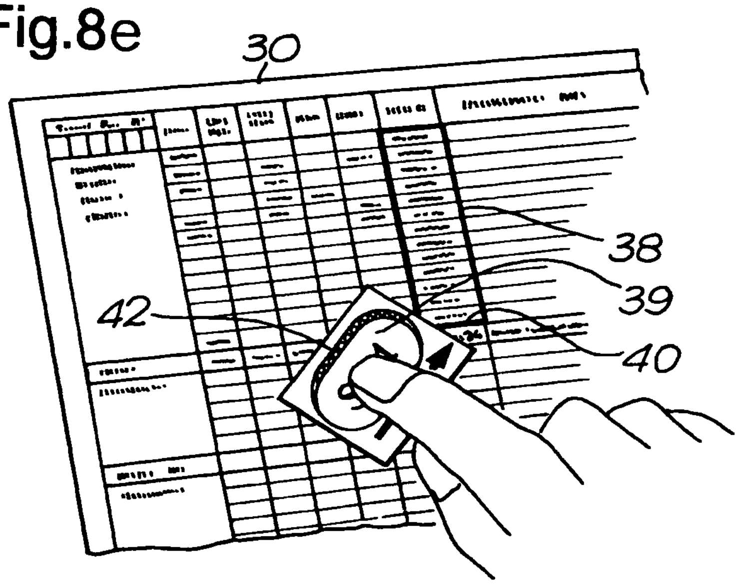

30
38
32

Fig.8e



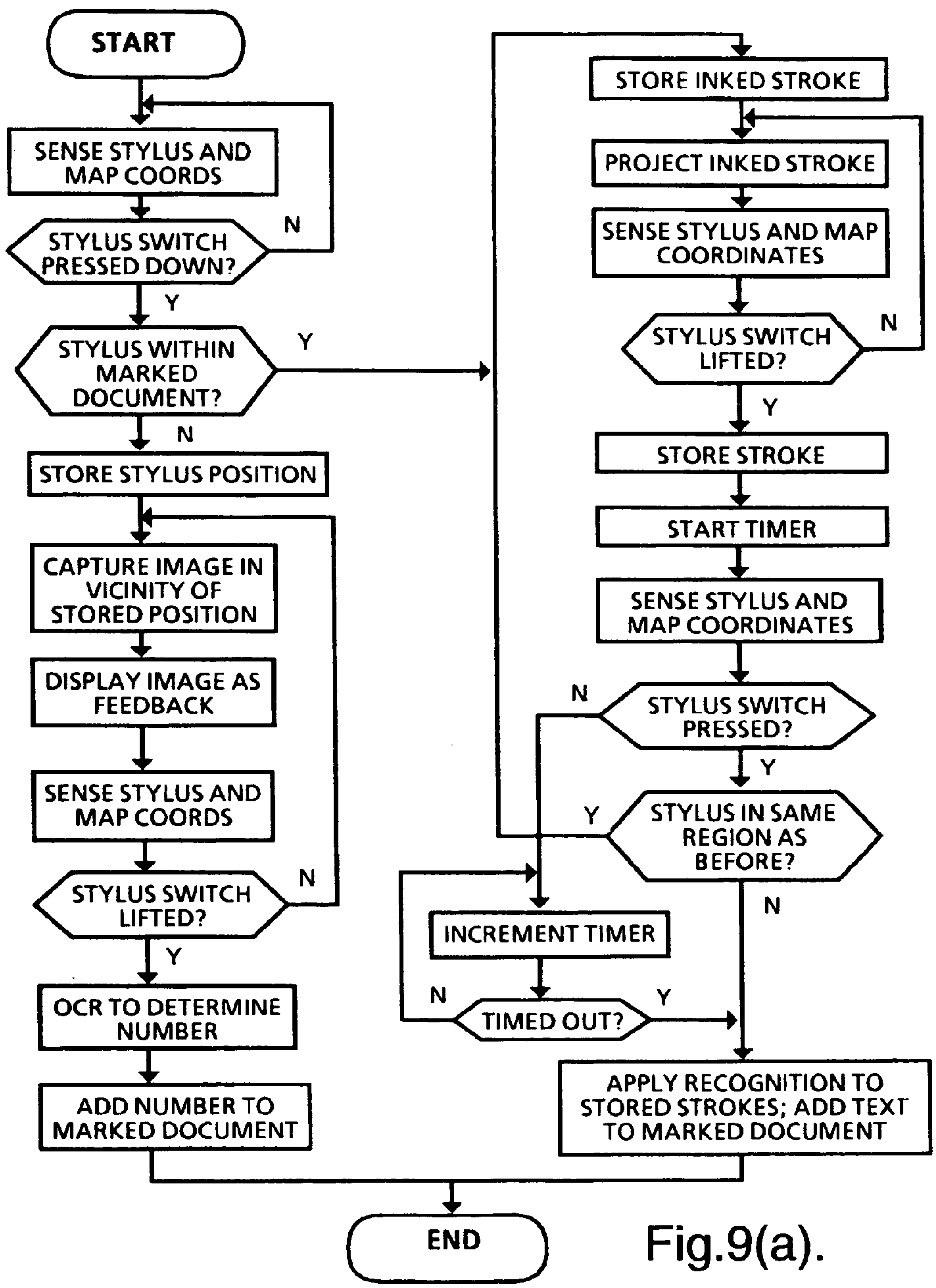

START
SENSE STYLUS AND MAP COORDS
STYLUS SWITCH PRESSED DOWN?
N
Y
STYLUS WITHIN MARKED DOCUMENT?
Y
N
STORE STYLUS POSITION
CAPTURE IMAGE IN VICINITY OF STORED POSITION
DISPLAY IMAGE AS FEEDBACK
SENSE STYLUS AND MAP COORDS
STYLUS SWITCH LIFTED?
N
Y
OCR TO DETERMINE NUMBER
ADD NUMBER TO MARKED DOCUMENT
STORE INKED STROKE
PROJECT INKED STROKE
SENSE STYLUS AND MAP COORDINATES
STYLUS SWITCH LIFTED?
N
Y
STORE STROKE
START TIMER
SENSE STYLUS AND MAP COORDINATES
STYLUS SWITCH PRESSED?
N
Y
STYLUS IN SAME REGION AS BEFORE?
Y
N
INCREMENT TIMER
TIMED OUT?
N
Y
APPLY RECOGNITION TO STORED STROKES; ADD TEXT TO MARKED DOCUMENT
END

Fig.9(a).

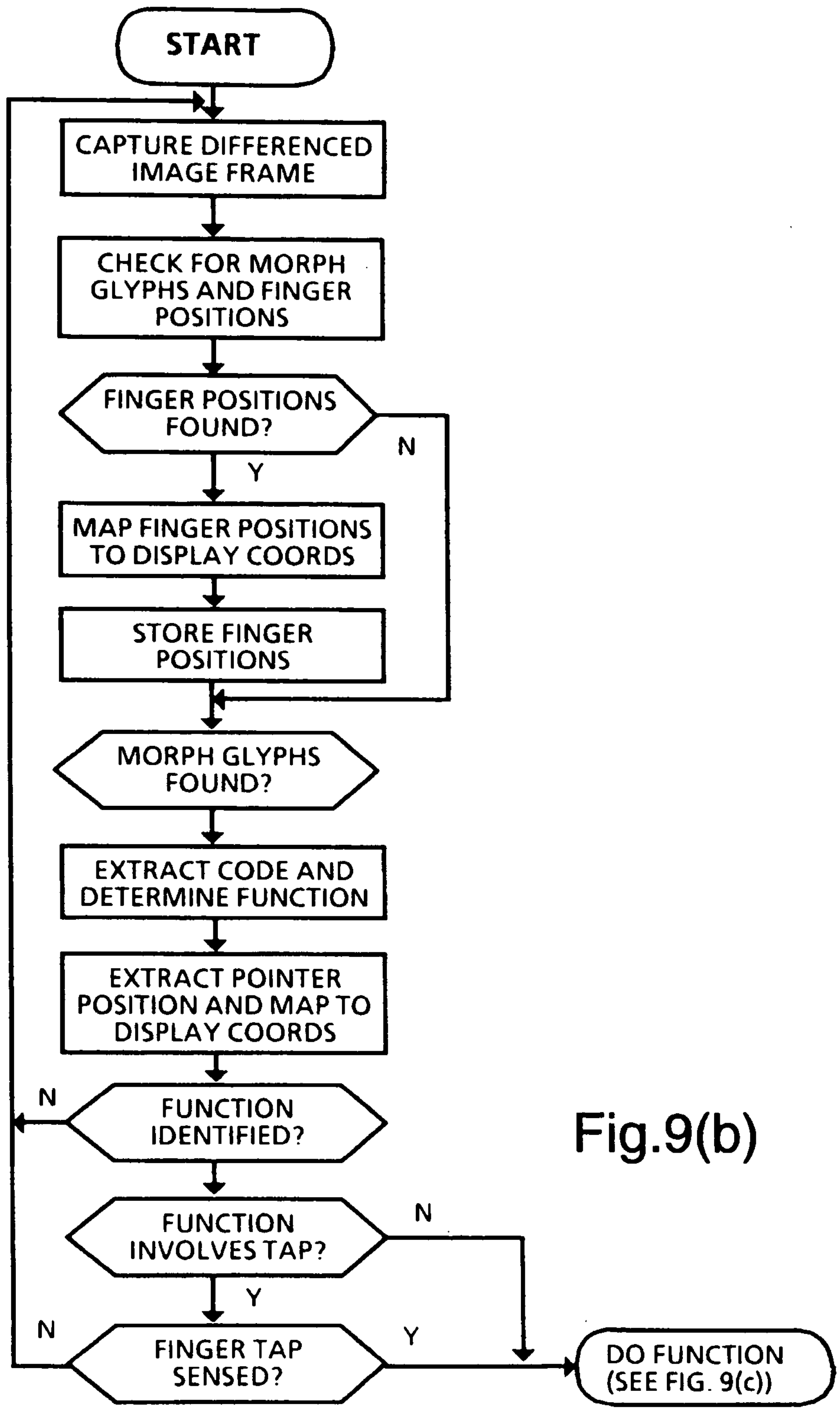

START
CAPTURE DIFFERENCED IMAGE FRAME
CHECK FOR MORPH GLYPHS AND FINGER POSITIONS
FINGER POSITIONS FOUND?
N
Y
MAP FINGER POSITIONS TO DISPLAY COORDS
STORE FINGER POSITIONS
MORPH GLYPHS FOUND?
EXTRACT CODE AND DETERMINE FUNCTION
EXTRACT POINTER POSITION AND MAP TO DISPLAY COORDS
N
FUNCTION IDENTIFIED?
FUNCTION INVOLVES TAP?
N
Y
N
FINGER TAP SENSED?
Y
DO FUNCTION (SEE FIG. 9(c))

Fig.9(b)

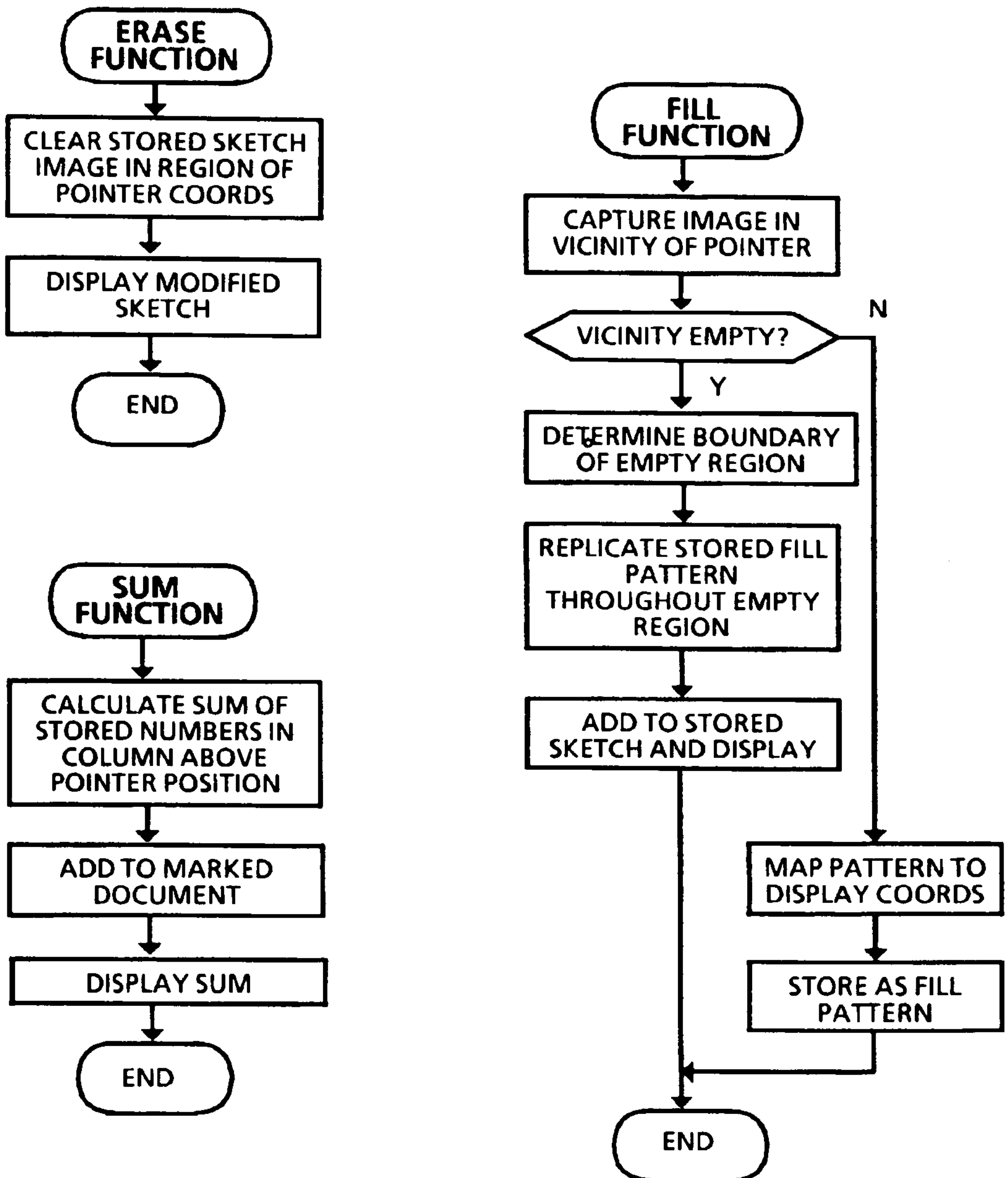

ERASE FUNCTION
CLEAR STORED SKETCH IMAGE IN REGION OF POINTER COORDS
DISPLAY MODIFIED SKETCH
END
SUM FUNCTION
CALCULATE SUM OF STORED NUMBERS IN COLUMN ABOVE POINTER POSITION
ADD TO MARKED DOCUMENT
DISPLAY SUM
END
FILL FUNCTION
CAPTURE IMAGE IN VICINITY OF POINTER
VICINITY EMPTY?
N
Y
DETERMINE BOUNDARY OF EMPTY REGION
REPLICATE STORED FILL PATTERN THROUGHOUT EMPTY REGION
ADD TO STORED SKETCH AND DISPLAY
MAP PATTERN TO DISPLAY COORDS
STORE AS FILL PATTERN
END

Fig.9(c).

Fig.10a

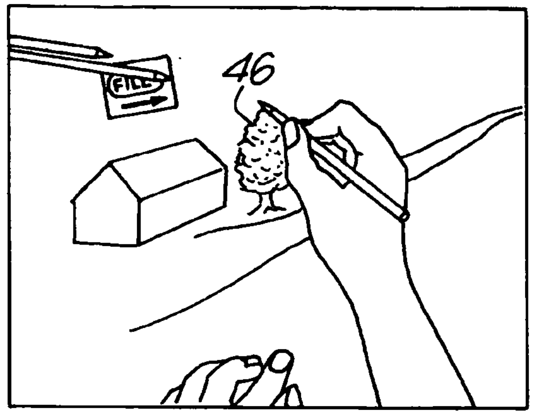


Fig.10b

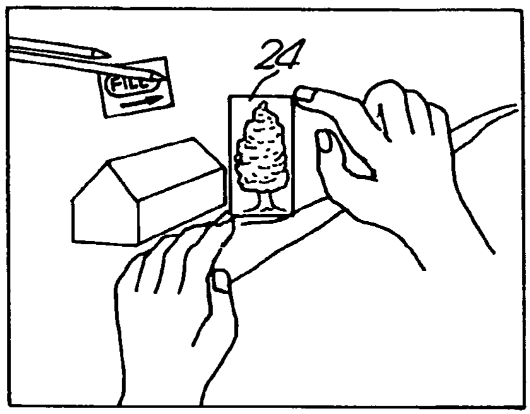
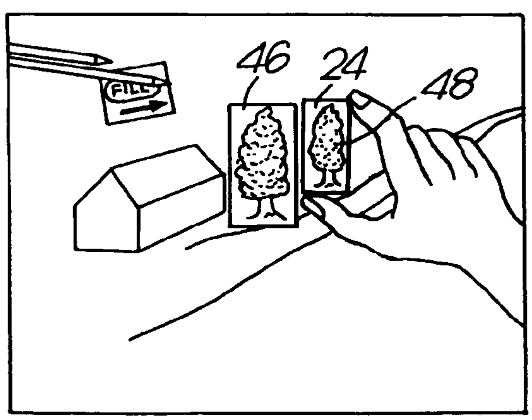


Fig.10c



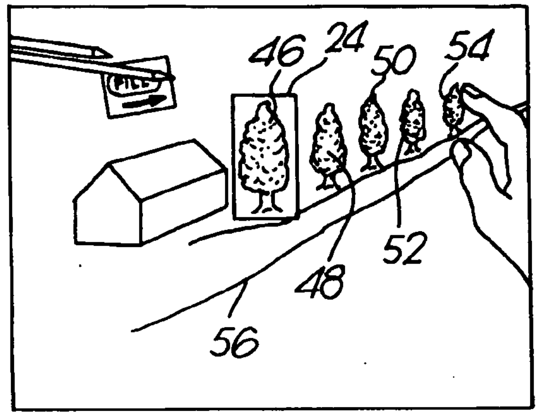


Fig.10d

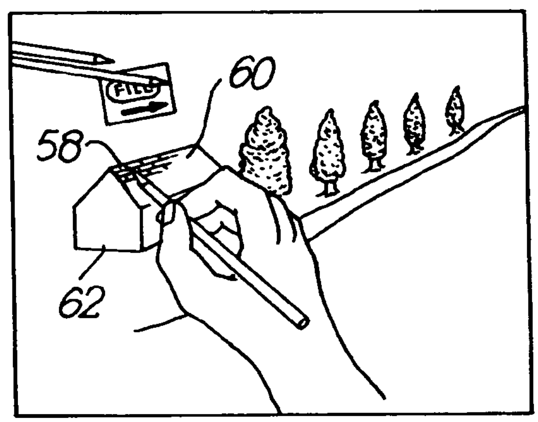


Fig.10e

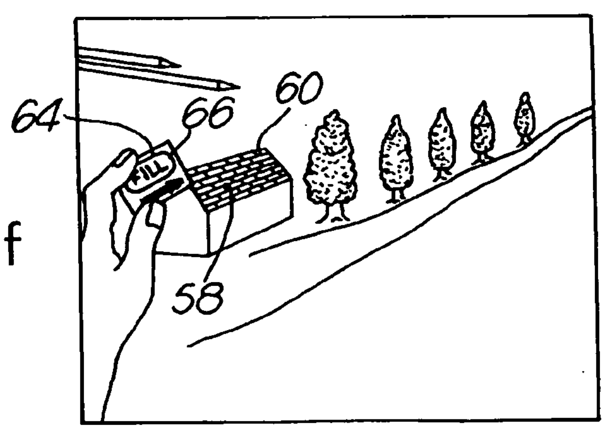


Fig.10f

Fig. 10g

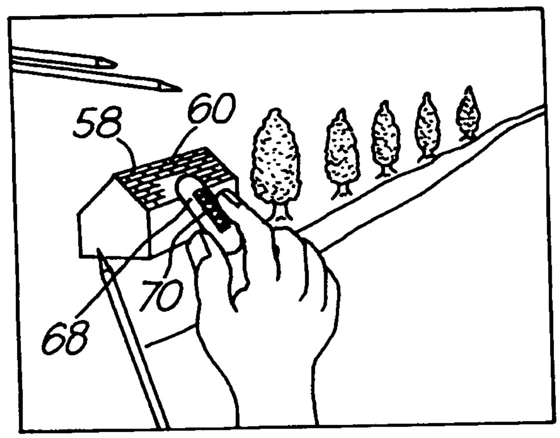
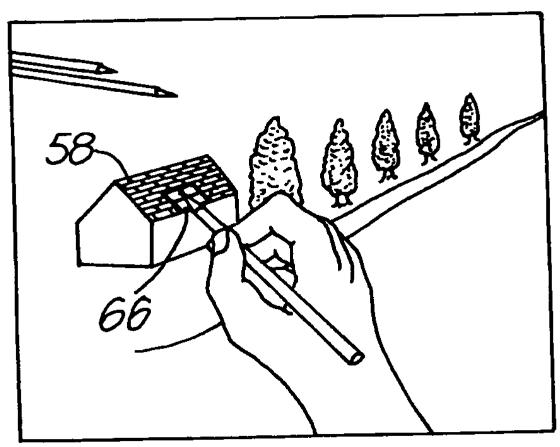


Fig. 10h



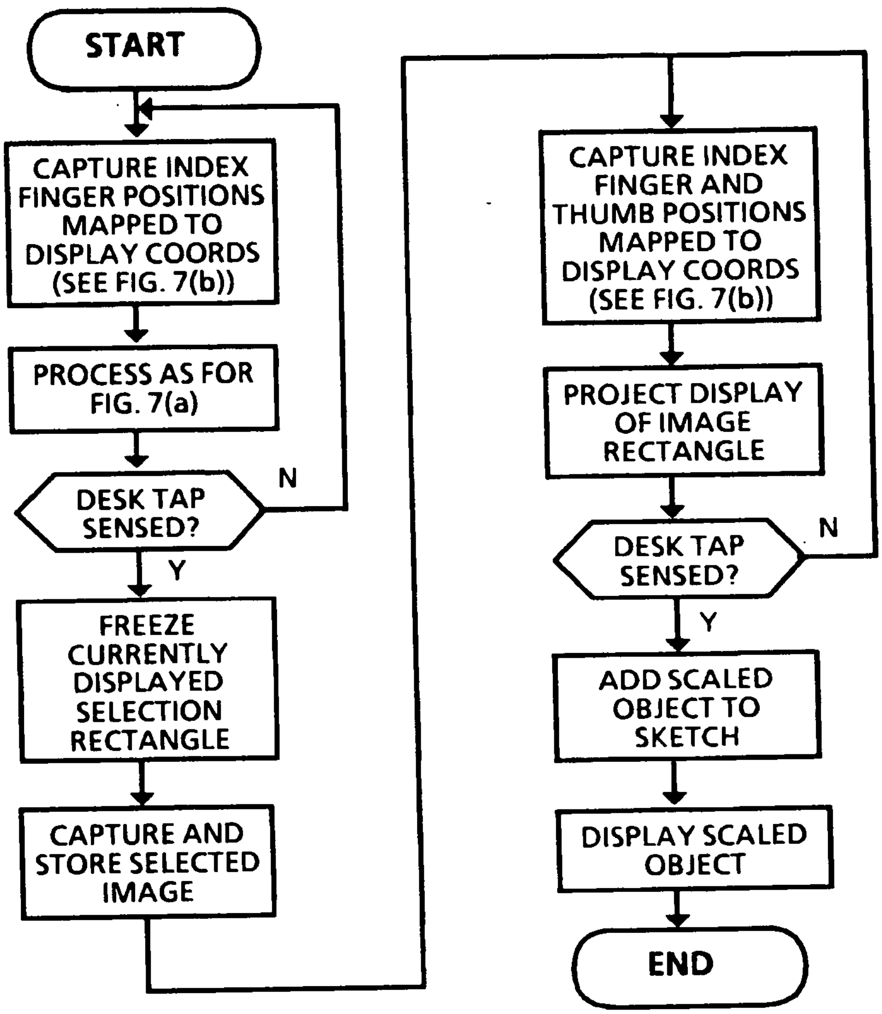

START
CAPTURE INDEX FINGER POSITIONS MAPPED TO DISPLAY COORDS (SEE FIG. 7(b))
PROCESS AS FOR FIG. 7(a)
DESK TAP SENSED?
N
Y
FREEZE CURRENTLY DISPLAYED SELECTION RECTANGLE
CAPTURE AND STORE SELECTED IMAGE
CAPTURE INDEX FINGER AND THUMB POSITIONS MAPPED TO DISPLAY COORDS (SEE FIG. 7(b))
PROJECT DISPLAY OF IMAGE RECTANGLE
DESK TAP SENSED?
N
Y
ADD SCALED OBJECT TO SKETCH
DISPLAY SCALED OBJECT
END

Fig.11

Fig.12.

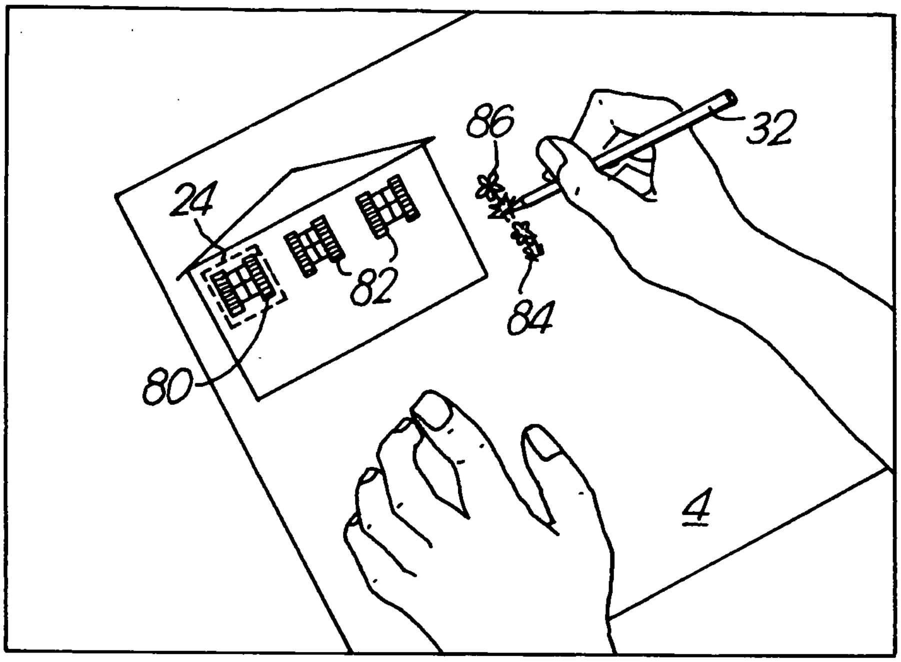
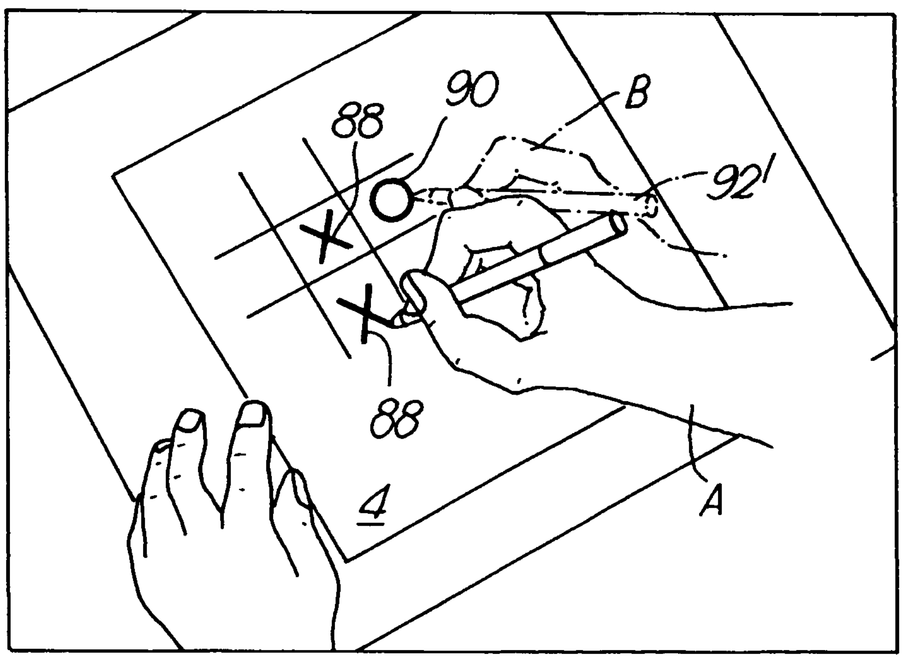


Fig.14.



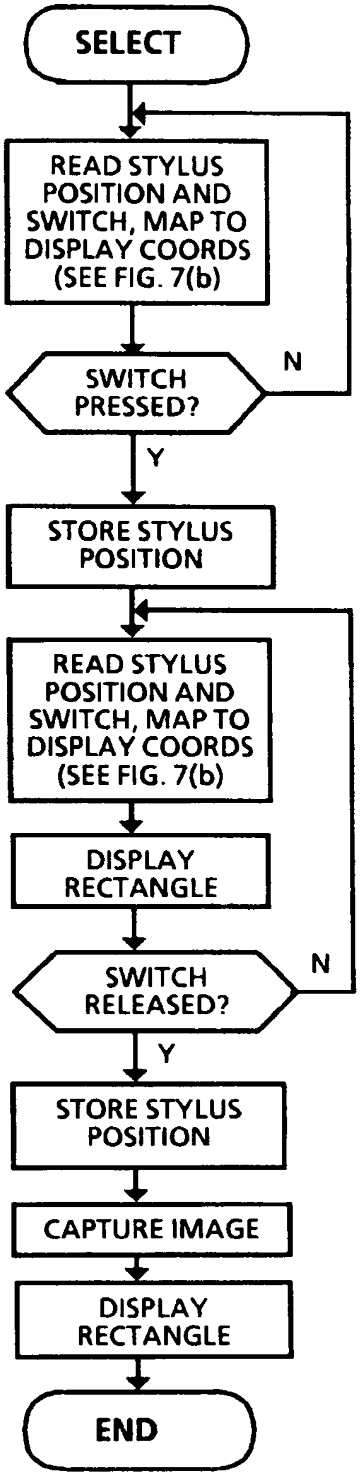


Fig.13(a).

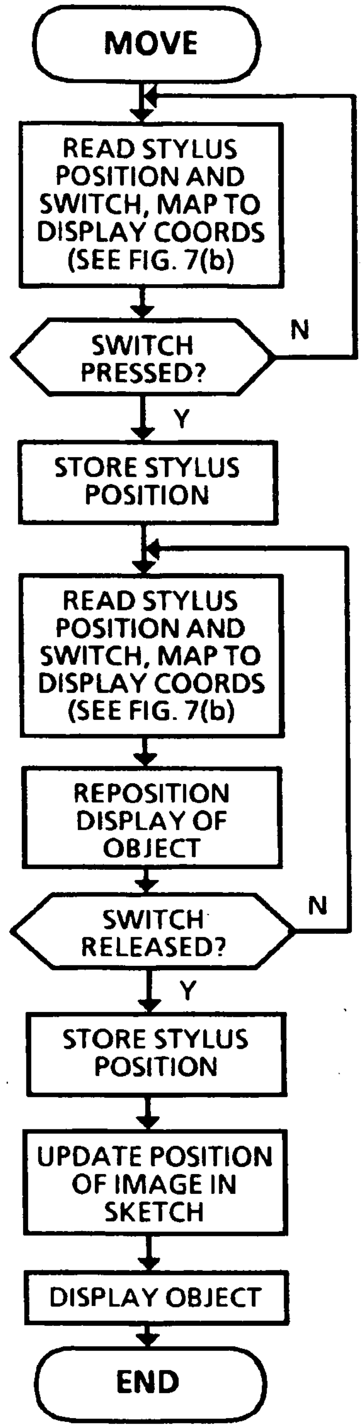


Fig.13(b).

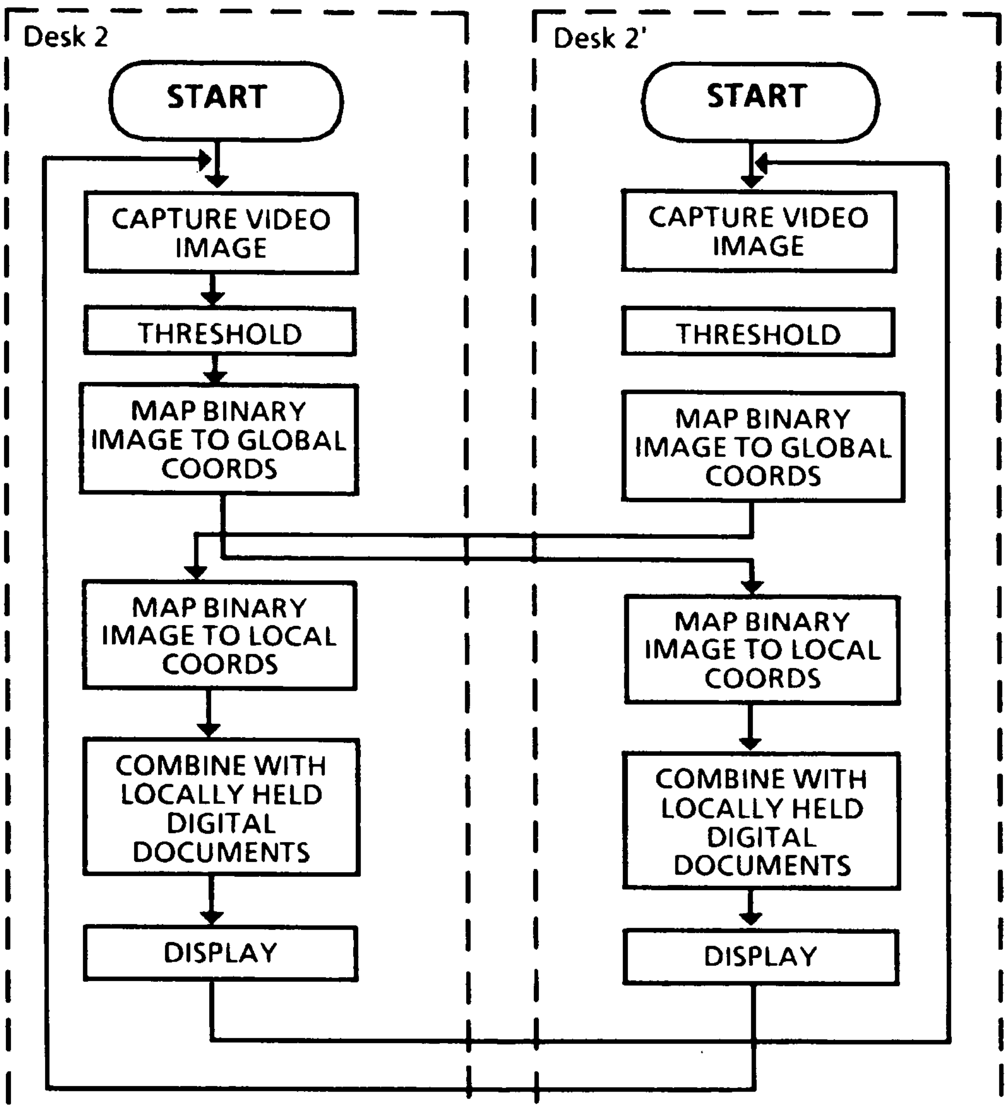

Desk 2
START
CAPTURE VIDEO IMAGE
THRESHOLD
MAP BINARY IMAGE TO GLOBAL COORDS
MAP BINARY IMAGE TO LOCAL COORDS
COMBINE WITH LOCALLY HELD DIGITAL DOCUMENTS
DISPLAY
Desk 2'
START
CAPTURE VIDEO IMAGE
THRESHOLD
MAP BINARY IMAGE TO GLOBAL COORDS
MAP BINARY IMAGE TO LOCAL COORDS
COMBINE WITH LOCALLY HELD DIGITAL DOCUMENTS
DISPLAY

Fig.15